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Information Innovation Intangible Economy

Virtual Worlds and the Transformation of Business:

Impacts on the U.S. Economy, Jobs, and Industrial Competitiveness

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Athena Alliance

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About Athena Alliance

Athena Alliance is in the vanguard of identifying, understanding, analyzing, and educating on the information, intangibles, and innovation (I^3 or I-Cubed) economy. Information, knowledge, and other intangibles now power economic prosperity and wealth creation. Intangible assets—worker skills and know-how, informal relationships that feed creativity and new ideas, high-performance work organizations, formal intellectual property, brand names—are the new keys to competitive advantage. Intangibles and information drive our innovation process, a combination of formal research and informal creativity. These elements combine to create productivity and improvement gains needed to maintain prosperity.

While the economic rules have changed, public policy has not caught up. Governments are struggling with ways to utilize information, foster development of intangibles, and promote innovation and competitiveness in this new economy. Policymakers are grappling with the urgent need to frame policy questions in light of the changing economic situation.

Issues of developing and utilizing information, managing intangibles, and fostering innovation underlie discussions on a variety of subjects, such as intellectual property rights, education and training policy, economic development, technology policy, and trade policy. Crafting new policies in these areas requires infusing a better understanding of intangibles and the information economy into the public debate.

As a nonprofit public policy research organization, Athena Alliance seeks to close the gap between the changed economy and current public policy through activities to reshape the debate and craft new solutions. Recent activities include working with the District of Columbia to create an innovation-led economic development strategy, co-hosting Congressional luncheon briefings, co-hosting a DC-based conference on innovation in India and China with the National Academy of Sciences, co-hosting a New York City-based conference on financial reporting and intangibles with the Intangible Asset Finance Society, and publishing policy reports on intangible assets, including *Reporting Intangibles* (2005) and *Measuring Intangibles* (2007).

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About the Author

Robert B. Cohen is an economist who has worked on the emergence of new communications and computer technologies. He has analyzed the business impacts of the growth of broadband communications and the Internet in the US, Asia and Europe with sponsorship from the European Commission and a number of US corporations. He has done similar studies of enterprise adoption of grid computing for North Carolina, California, the US and Japan. He has been a board or advisory board member of several Internet and software startups. As a market analyst, he has studied business strategies of many key players in the telecom and grid computing industries. He has also been an international trade and telecommunications policy expert at the Economic Strategy Institute for nearly two decades. Dr. Cohen also serves on the steering committee of the Open Grid Forum, the professional organization for Grid computing, where he is Area Director for Enterprise Requirements.

Dr. Cohen has done extensive work on industries and competitiveness. He was a main contractor for the Congress' Office of Technology Assessment's study of US industrial competitiveness and served on the board for OTA's analysis of service industries. He prepared studies on US global competitiveness for UNIDO, wrote one of the earliest studies of non-tariff barriers and high technology trade, and authored papers on banking issues for the Congress' Joint Economic Committee.

Dr. Cohen has a long association with high tech policy. For New York's Governor Mario Cuomo, he developed the state's high tech strategy and served as secretary of the state's High Tech Council. For President George H.W. Bush's National Advisory Commission on Semiconductors, he was the economic advisor and worked with Bob Galvin and Jerry Junkins. He helped the European Commission's Advanced Communications Research program formulate policies to promote the growth of the Internet and research on future communications. He analyzed the speed of consumer adoption of HDTV for the FCC's Working Party 4 on HDTV. Dr. Cohen has taught at several universities, including NYU's Stern School of Business, the City University of New York, Cooper Union, and Columbia University. He worked at TASC and the Futures Group and is a past president of the Forecasters Club of New York. Dr. Cohen holds an MA and Ph.D. in economics from the New School in New York and a BA from Swarthmore College. He is the co-author of several books on trade policy.

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Introduction

Virtual Worlds, immersive and collaborative environments on the Internet, also referred to as Web 3D, are likely to transform the global business environment. Developed out of online games, social networking, and Web services, Virtual Worlds benefit from several technologies that enhance their usefulness, including massively scaled games, avatars, cloud/on-demand/grid computing, on-demand storage, and next-generation networks.

The convergence of these technologies in a new Virtual World "ecosystem" will change the way businesses operate. By creating immersive environment platforms accessible through mobile and other handheld devices, Virtual Worlds bring powerful computing, data analysis, and decision-making tools to employees of firms of any size.

Virtual Worlds not only elicit customer-generated information and ideas, they enhance collaboration within and between businesses. These platforms facilitate a wide range of business activities and opportunities, such as training and education, product and service development, marketing and strategy creation, and finance exchange, that can be executed in new, interactive environments. By enriching and deepening collaboration within and between firms, Virtual Worlds can transform U.S. businesses in the modern era.[1] This vision—now plausible with current and ever-evolving technology—sees the modern corporation operating and receiving knowledge and inputs from suppliers, employees, and customers in wholly new ways. It also provides for the emergence of highly specialized very small firms that can combine to create innovative products when opportunities for these exist. This offers a vision of a modern guild-like part of the economy.

For the past few decades, business organizations have integrated new technologies into their operations using structures to capture new knowledge and innovations. Several authors have argued that the corporation should move toward the collaborative enterprise, which incorporates the Internet more fully.

Here we argue that online social networking and Web 2.0 platforms are likely to transform core business operations and interactions with suppliers, customers, and supporting services. Virtual Worlds platforms that form the core of a new corporate operations ecosystem will not only allow for horizontal and vertical interactions but will expand the essential business, partner, and management linkages that enhance productivity over the long term.

Virtual World environments promote such changes by helping enterprises develop new products in concert with suppliers as well as with specialized "expert firms" or individual entrepreneurs. In these immersive, collaborative environments, corporate executives and other employees can bring computer simulations and robust databases into Virtual Worlds supported by high-speed, next-generation networks. This allows a wide range of businesses, manufacturing concerns, and services to see the results of business decisions in real time. For instance, banks can visualize analyses of equities data or of options prices and make rapid decisions about where to direct investments.

In some cases, this tool will expand the modern corporation; in others, it will lead to greater specialization.

For example, one scenario envisions a multi-industry conglomerate that acquires or merges with companies in related industries and their suppliers and operates in major parts of the economy. A new conglomerate emerges, for instance, to serve both the aerospace and auto industry and includes suppliers that were once independent of final producers.

Another scenario might result in a modern guild system wherein firms employ extensive Virtual Worlds technology to foster collaboration both inside and outside the firm. These expertise-based firms will be far more capable of amassing specialized knowledge than other, more traditional suppliers or service firms. They also will be better positioned to team up with other "guild system" firms to respond to large projects or to jointly address significant technical challenges. These modern guild firms might be similar to large consulting firms or to today's highly specialized supplier firms like KPMG, Cadence Design, or Mentor Graphics, although we assert they'd go even further.

We might call them "extremely agile" corporations that can quickly and effectively acquire new products and recognize new benefits from technological innovation and services development.

These emerging collaborative enterprises will use existing Virtual World and social networking technology to form new ecosystems that are three-dimensional immersive environments that can be secured behind a firewall either online or within the corporation's intranet system or in secure extranets that are outside of corporate firewalls.

The evolution of the Internet to Web 3D or fully functional Virtual Worlds will require extensive use of cloud/on-demand/grid computing, on-demand storage, and next-generation networks. These three technologies will allow businesses to take compute-intensive processes, such as product design, investment decisions, and daily business problems, and bring them under the control of a wide range of corporate executives. This will enable business collaboration on a heretofore-unimaginable scale and scope. Furthermore, embracing these three new technologies makes it possible for corporations to make the social networking organization the central tool for integrating supplier and partner expertise into their own operations, either temporarily or permanently. This will transform both manufacturing and services-oriented businesses and the U.S. economy as a whole.

Some of these Virtual World technologies are used in business today. Several Virtual World sites have millions of registered users; the total number of users is expected to grow to one billion worldwide by 2017. As of May 2008, IBM's Virtual World connected at least 6,000 active employees. Sulake's Habbo Hotel has nearly 100 million registrants and 10 million unique monthly visitors. Linden Lab's Second Life reported 12 million registrants and about one million active users.

Many businesses also use cloud computing. Amazon offers cloud computing to serve many small and large corporations. CERN, the world's largest particle physics lab, located outside Geneva, uses cloud to link its many scientific computers into a global computing grid that analyzes particle interactions. Google, Amazon, and Microsoft have all built cloud-computing and on-demand data centers to support their businesses. IBM, Morgan Stanley, and other firms are building a substantial cloud-computing infrastructure that in one case will include more than 100,000 processors.

The International Telecommunications Union and many large communications equipment firms are working assiduously to plan for next-generation networks. Japan plans to build a next-generation network by 2010 that has a capacity of nearly a petabit-per-second and gigabit-per-second access capacity for each user. By 2015, Japan's next-generation network capacity will exceed one petabit per second, with at least 10-gigabits-per-second access for each user. This will be roughly 100 times the speed of current scientific connections for the Internet.

This essay draws a bold vision for the future of business based on an understanding of how key technologies and online social networking will transform business. There is a quiet revolution taking place outside the view of most business and political leaders. This paper aims to alert the wider world to the tectonic changes in business brought about by new and emerging technologies and to encourage their use in making transformational changes in the marketplace.

The modern corporation took shape in this country in the late 19th and early 20th century, and, with it, the concept of mass production took hold. Corporations adopted "lean production" systems that employed mass customization.

What this paper describes is how corporations in this century will begin to use new technologies to transform the methods of production, the generation of services, and the management of people and processes.

To make our case, this paper:

1. Explains Virtual Worlds and how on-demand/utility/grid computing, on-demand storage, and next-generation networks support their commercialization.

2. Explores how Virtual Worlds and the technologies that support them can change the nature of the firm and influence collaboration in business.

3. Describes the changes that give rise to collaborative enterprise, including the two likely main forms of organization: the multi-industry conglomerate and the modern guild system. We also explore how enhanced collaboration has the power to extend and alter the ways in which today's firms create products and services and redefine relationships with suppliers and customers.

4. Discusses how Virtual Worlds and supporting technologies will affect U.S. industrial competitiveness and provides policy recommendations in a number of areas, including deployment and adoption of Virtual Worlds, collaboration, skills development, and the ideal business environment needed for full and rapid adoption of these new technologies.

The rise of the collaborative enterprise that is likely to result from the successful deployment of Virtual World technologies will usher in a new era of business. It will change the way firms compete with one another for customers in both goods and services industries.

It is our firm belief that if our nation accelerates the development and maturation of Virtual Worlds, it will encourage a more collaborative and enterprising form of business. This will lead to greater innovation, sustained productivity, and competitive growth in the world economy.

It will also create challenges. The ability of manufacturing, service, and knowledge-based businesses to find whatever inputs they need regardless of their geographical location poses a specific trial. Virtual Worlds could engender new forms of outsourcing or place the United States at a competitive disadvantage if firms around the world were faster to adopt Virtual Worlds than their U.S. counterparts.

Thus, the need for the United States to move quickly is great. This paper lays out a number of policy areas. These include policies: to heighten the awareness of the importance of Virtual Worlds and the collaborative enterprise to the economic competitiveness of the nation; address the need for the technical infrastructure; encourage adoption of these collaborative tools and deploy these tools everywhere, including in communities left behind; and promote the education and training that employees and businesses will need if they are to successfully work as collaborative enterprises.

With the right policies in place, the companies and workers can use the tools of Virtual Worlds to transform the United States into a collaborative enterprise-driven economy. As a result, this new phase of business can potentially create millions of well-paying jobs for the people of the United States and sustain American prosperity for years to come.

Virtual Worlds, Collaboration, and Competitiveness

The 21st century economy is marked by a rapid shift to collaborative work structures. This shift is, in part, embodied in the rise of new technologies and new competitive pressures. This section describes how the present environment for collaboration is likely to change as new technological innovations are widely adopted and, as a result, competitiveness in business adapts.

A New Context for Collaboration and Competitiveness

The Internet improves collaboration by making it easier to exchange large data files, share analysis, and link work groups. Many firms want to link their research and development (R&D) centers more closely because they depend on the exchange of valuable results and tests. But they find that these R&D centers often cannot work as unified teams. Rarely do R&D-intensive firms feel that key players in disparate locations are working as a unified team, interactively exchanging insights on projects as though they are in the same space.[2]

Several new technological innovations are changing Internet-based collaboration: Web3D[3] or Virtual Worlds[4], including multiplayer games and avatars; cloud-computing platforms and solutions, such as "software as a service"; and next-generation networks. Changes in these areas will affect the way businesses use the Internet, computing, and networking. Besides speeding computations and reducing the cost of computing and software, these changes have the potential to transform the collaboration environment. By shifting firm-level collaborations from a largely noninteractive, isolated set of R&D centers to immersive Internet-based environments that foster exchanges among all members focused on a single project, technological shifts could dramatically change the way enterprises work together. While the magnitude of this change is difficult to measure right now, the transformation when fully realized could rival the very advent of the commercial adoption of the Internet nearly a decade ago.

Massively multiplayer online games (MMOGs) certainly influenced the development of Virtual Worlds. [5] But, as Cory Ondrejka has pointed out, MMOGs differ in several respects. They include strong game fictions and leveling:

> Strong game fictions mean the games take place within relatively cohesive settings that discourage intermingling with the real world. Fantasy motifs are common, but certainly not the only option. Leveling is the process of measuring progress via increases in experience points. These experience points are gained by activities appropriate to the level, and each new level grants the player access to new abilities or game features.[6]

In contrast, Ondrejka notes Virtual Worlds have other characteristics:

> While still massively multiplayer, meaning that thousands of players simultaneously experience the world in a shared space, they possess neither strong fictions nor leveling. Instead, their defining characteristic is the ability of

> residents to generate creations of value within a shared, simulated, 3D space. Strong, predefined fictions are not appropriate, as they limit the design space available to the residents. Instead, residents create their own fictions and communities, imbuing them with meaning through interaction.[7]

Ondrejka goes on to cite the example of stroke survivors establishing their own group within Second Life, where they promoted post-stroke cognitive recovery. In this effort, participants can be effective because they are freed of the limitations in MMOGs, including strong fictions and leveling.

Games provide the ability to learn new skills, fill new roles, and benefit from a more “robust” peer-to-peer learning process that many people can benefit from without needing to travel, pay for the cost of education, or enter traditional educational institutions.[8] These benefits, as well as basic game technology, have proven to be enormous assets for Virtual Worlds.

In addition, Virtual Worlds have benefited from the improved performance of computers and mobile devices. [9] With greatly improved graphics and multi-core processors and the ability to draw upon new input devices, Virtual Worlds gain from a more resource-rich environment where higher resolution will make interactions more lifelike, providing the means for many more users to experience “augmented” reality and see how developments in Virtual Worlds can be more closely tied to experiences in Real Worlds.

According to Ondrejka, Virtual Worlds, including Second Life, have the ability to:

> leverage the place, embodiment, and simultaneous collaboration at the core of interactions within virtual worlds. Place grants both context and organization to conversations, helping an observer to immediately understand relationships between speakers and the topic being discussed. Avatars, the user’s representation in a virtual world, embody the conversation, allowing real-world cues to flow into the virtual world. Simultaneous collaboration allows multiple participants to interact in ways not commonly seen on the web, such as musicians in different cities playing a duet to an audience from all over the world. This real-time exchange is at the core of how content is created within Second Life.[10]

The main point about Virtual Worlds is that they enhance collaboration and innovation.

In the history of manufacturing and growth of service industries in this country, collaboration has been between groups within a firm or between suppliers and final manufacturers or service providers. In many cases, collaborating groups were isolated geographically, with travel used for coordination. When all the parties in such collaborations were not in close proximity, they could work on subparts of a product that was managed regionally or globally. Separate groups would have their own tasks and feed results into a final product or service. Periodic progress reviews would take place.

Corporations have raced to develop global research networks. Between 1975 and 2004, the share of R&D centers located in foreign sites for 186 of the largest global firms rose from 34 percent to 66 percent.[11] In spite of this diffusion of research, the number of "projects undertaken across multiple sites is relatively low, at an average of just 36 percent of all projects performed," according to Booz Allen Hamilton.[12] Consequently, the benefits of global innovation networks—primarily shortening time to market and reducing the costs of developing new products—have been marginal. If companies improve how different R&D and product-development groups and suppliers interact, they might achieve much larger efficiencies. For instance, Booz Allen Hamilton "projected that [large corporations] could achieve a 37 percent faster time-to-market and 24 percent lower costs with an innovation network that was efficiently organized and integrated."[13] Firms could also bring the customer directly or indirectly into all parts of the design and development processes for services and products at the earliest possible time.

Small firms have also benefited from the increased collaboration and innovation that we illustrate for larger firms. It is easier to obtain data to describe the growing global connections with larger firms, but a number of experts on Second Life, including Ondrejka, have noted the hundreds of firms that have fostered geographically unlimited collaboration to speed the development of startup companies. [14] So collaboration in Virtual Worlds and the Real World characterizes a wide range of firms.

Web 3D immersive environments are likely to transform the environment for collaboration by providing for the immediate exchange of ideas and sophisticated analyses, such as simulations performed on new cars or airplane designs.

Recent early experiments using Virtual Worlds bear this out. Some companies already have groups that meet in Virtual Worlds to coordinate plans for a team that can be dispersed around the globe. Other firms and the U.S. government are using Second Life to train employees, saving travel and hotel costs by not having to bring 20 or 30 employees to a single location and instead coordinating them in a virtual environment. Some firms plan to bring company employees, outside suppliers, and technical experts to secure Virtual World sites where, for instance, a planned oil exploration project can be reviewed in detail. In all of these cases, business teams work as a single, collaborative group.

In contrast to audio or video conference calls, employees are able to see a report or a new product design in realistic detail and interact with any presenters. In some instances, the computing power of individual participants can be tapped to run an application that will display results for all to see. It is this sense of "connectedness"—and the associated ease of exchanging thoughts—that makes Virtual World settings ideal for establishing a sense of cohesiveness. Virtual World participants feel part of a "team" rather than lone participants on a call. Indeed, by providing additional ways for participants to communicate after the Virtual World meeting, employees in California, Germany, and India may even fundamentally change the way they think about coworkers whom they've never met in person.

In the future, Virtual World participants will very likely be linked via broadband connections that can increase in scale as more bandwidth is acquired. They will also be able to access computing and storage resources on demand. This broadening of the resources that can be brought into a Virtual World meeting would expand the type of tasks that participants could complete in sessions. This, in turn, would help firms achieve greater benefits through both time to market and cost savings.

Our argument is that innovations in several interrelated technologies have the potential to alter the environment for collaboration and create a new work ecosystem—a new context for working together using the Internet, computing, and networks.

The next section will describe how this new ecosystem will greatly increase collaborative opportunities, possibly changing the nature of work, the modern corporation, and the future skills required in the workforce.

The key changes are quite revolutionary, although they often build on technologies that have been in use for decades. The revolutionary possibilities arise from the economic efficiencies that each change in technology—in the Internet, in cloud computing, and in networks—will bring about. This will create new contexts for linking work processes that could once only be completed by a team operating in the same physical workspace or networked space. Although video links people through networks, such collaboration is more contrived. In addition, incompatible software often is a barrier to interaction, as are different languages and work backgrounds.

New technologies will transform the Internet, the way working groups are linked, and the way people interact. First, Virtual Worlds create a 3D Internet experience that allows people to exist—in a virtual way—in a single space at the same time, in an immersive environment. While previous Internet-based interactive discussions or presentations tried to replicate a meeting place, this becomes more lifelike in Virtual Worlds. Second, as cloud computing—computer-based applications as well as computation and storage resources—becomes on demand and ubiquitous, work groups will call on it without difficulty. Third, networks are changing so that users can control the amount of bandwidth that is available for specific needs.

These next-generation networks will enhance the ability of users to access any program and make any communications links, which will unleash an unprecedented amount of work collaboration.

Elements of the New Technology for Collaboration

As noted above, a number of new technologies underpin the environment for increased collaboration, including Virtual Worlds, cloud computing, storage on demand, and next-generation networks. We review them all below.

Virtual Worlds

Colin Parris of IBM describes Virtual Worlds as:

> computer-based, simulated, persistent environments that support synchronous interaction between users personified as avatars. The avatar and environment representation can range from 2D "cartoon-like" to 3D "lifelike" imagery with the interactive interface capabilities.[15]

Figure 1. An IBM Island in Virtual Worlds. Source: Parris, C., IBM, *Online Virtual Worlds: Applications and Avatars in a User Generated Medium*, written testimony submitted to the House Committee on Energy and Commerce, Subcommittee on Telecommunications and the Internet, April 1, 2008.

Virtual Worlds are a further evolution of the Internet. They have the unique ability to act as a workspace. As Phillip Rosedale, the former CEO of Linden Labs, noted:

> In virtual worlds there is a sense of geographic "place" and personal "presence," even when users are miles or continents apart. In Second Life, you can "see" the other person, verbally speak with him, as well as chat with or "instant message" him. You occupy a multi-tiered communication platform with dimensions that do not exist with e-mail, telephone calls, conference calling, or other platforms. This vastly expands our ability to collaborate over distance: large (or small) groups can hold conferences; view evidence, charts and other content; do language training;

and design code, blueprints, and plans as if they were in the same room. Moreover, in a "virtual" atmosphere, even persons who have never met can establish rapport[16] and trust with one another. This is one reason why large companies are effectively using Second Life across distributed communities of employees. Other reasons are the ability to transfer and view information immediately in Second Life, along with low production and infrastructure costs and barriers to entry.[17]

Indeed, Microsoft has argued that Virtual Worlds or immersive environments will emerge as one of the dominant user experience waves by 2010–2105 and will be the dominant user experience after 2014.

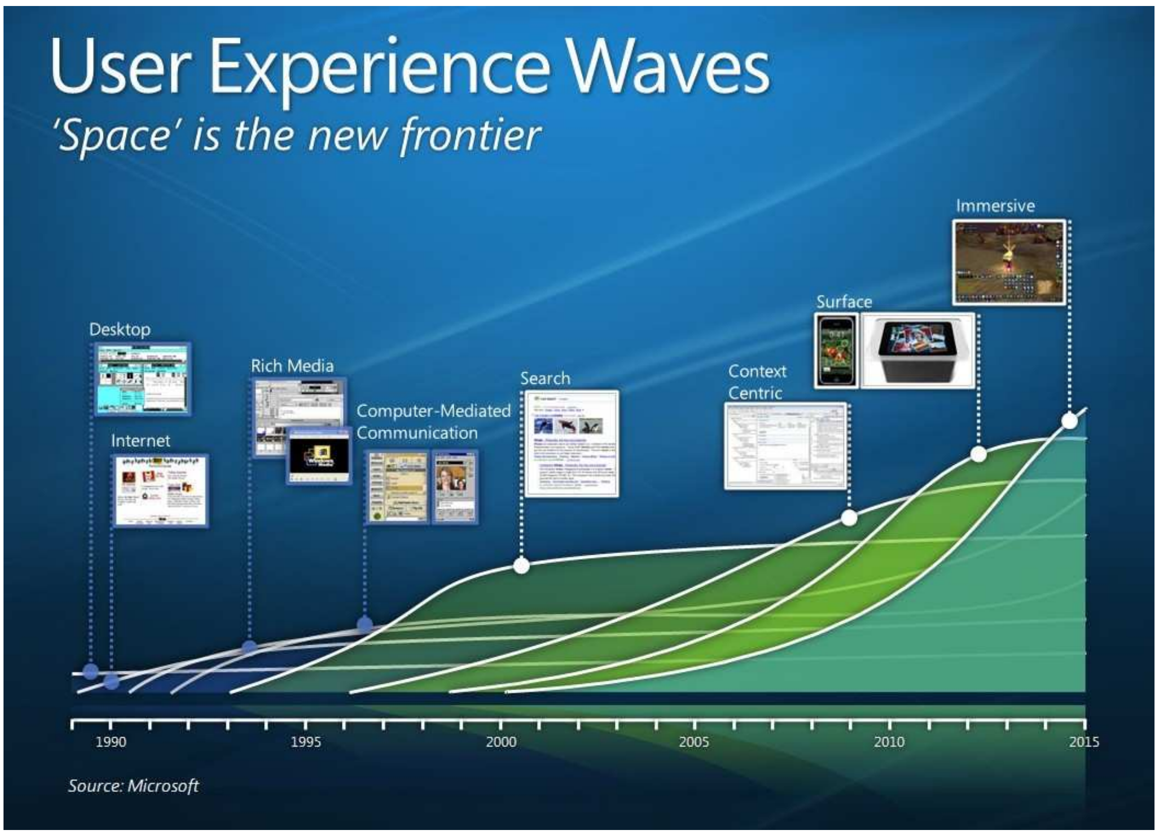

Figure 2. User Experience Waves. Source: Mundie, C., Rethinking Computing, keynote speech, Technology Review EmTech08 Conference, MIT, September 25, 2008. Published with permission of Microsoft.

Researchers at Stanford's Virtual Human Interaction Lab have also noted that the use of avatars can influence the perception people have of their self and their ability to act. [18] Avatars are a separate depiction of humans that can be quite different from what people are in the Real World. Jeremy Bailenson at Stanford has shown that "people can interact differently in virtual worlds than they would face-to-face."[19]

Virtual Worlds provide an environment that many youths, particularly preteens, have experienced from playing World of Warcraft or Neopets (with an estimated 45 million registered accounts) or Habbo (with an estimated 100 million accounts).[20] But most Americans over 20 have not experienced these collaborative worlds, where interaction with others is very different from interactions via video conferencing or Internet social networking. Virtual Worlds can be environments for collaboration that could transform the way enterprises operate.

Cloud Computing/Grid Computing

Cloud computing provides a new way for companies to access computing and storage resources. It moves our thinking about computing and storage from the physical level of machines to a conceptual one where computing and storage are available as services on demand. There is no need to purchase computers in order to run applications. By paying for a cloud-computing service from a vendor, one can access needed resources from almost any location. Cloud computing is a step beyond grid computing, where computers divide jobs up into their parallel parts and are contained in a singular ownership enterprise. With clouds, computer resources can be anywhere.

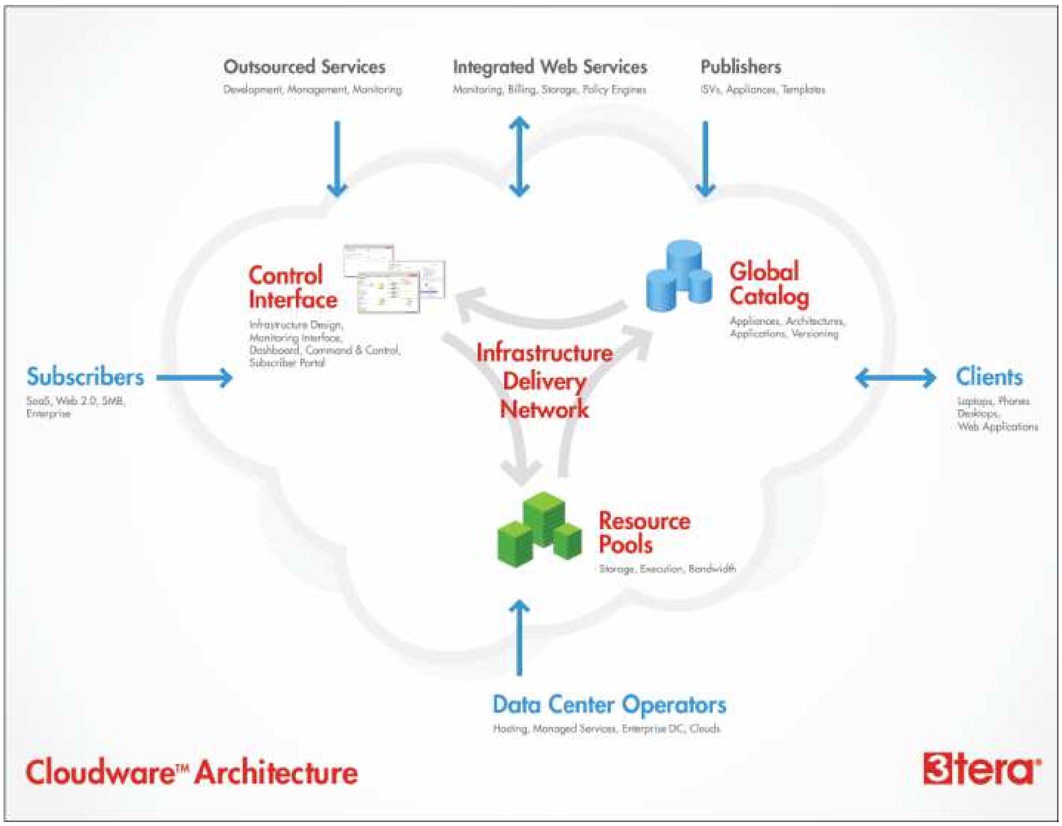

Figure 3. Cloud computing. Cloudware incorporates the fundamental building blocks used in developing today's most popular applications—storage and computing, software cataloging, and definition and control—and shows how they relate to each other. More importantly, the architecture is vendor agnostic, so that third-party vendors, not just 3tera, can participate. Source: 3Tera, *Cloudware—Cloud Computing Without Compromise*, http://www.3tera.com/Cloud-computing, accessed Nov. 24, 2008.

Cloud computing is important because it provides a technology by which intermediaries—Amazon, Google, Sun, Salesforce.com, phone companies, and others—

can offer companies computing power and digital storage. While the definition of cloud computing is still being debated, linking compute power to applications that businesses or consumers want to run will provide several things that are not possible without this technology. A cloud-computing platform "dynamically provisions, configures, reconfigures, and deprovisions servers as needed. Servers in the cloud can be physical machines or virtual machines. Advanced clouds typically include other computing resources, such as storage area networks (SANs), network equipment, firewall, and other security devices."[21] Clouds can also include cloud-computing "applications that are extended to be accessible through the Internet. These cloud applications use large data centers and powerful servers that host Web applications and Web services."

IBM defines a cloud as a "pool of virtualized computer resources." By virtual, this means that what had been a physical machine before can now be represented as a machine without a physical presence. Virtual components can include computing resources, operating systems, software applications, and storage devices.

Since clouds provide "dynamic resource pools, virtualization, and high availability," there is a belief that they will help organizations reduce computer costs beyond what can be achieved through virtualizing machines and setting them up as pools of machines. Clouds achieve this because they offer "improved utilization, reduced administration and infrastructure costs, and faster deployment cycles."[22]

The use of cloud computing is becoming popular because its economic logic is compelling. With compute resources available on demand, firms are no longer limited to the physical compute and data storage they have on hand. If they need to, they can access supplementary resources and use computers from a cloud provider to run applications. This approach often draws upon programs or applications that are requested and paid for as they are used. Such cloud-computing applications are usually described as "Software as a Service" or SaaS. In addition, cloud computing lets enterprises, including small startup firms, get away from the constraints of having to purchase enough computers and data storage to meet peaks in demand. With cloud-computing services, enterprises can estimate their usual requirements and contract with any on-demand resource provider to pay for extra compute power and storage resources, as needed.

One of the first cloud services is Amazon's Cloud, which includes cloud computing and storage. Amazon's Elastic Compute Cloud (Amazon EC2) and Amazon's Simple Storage Service (Amazon S3) permit small firms to use computing and storage on demand. One example of this is the applications firm Morph Labs:

> Morph Application Platform brings together the best of open source technologies and integrates them along with Morph's own technology to provide a seamless end-to-end virtualized infrastructure for applications. Developers and ISVs can quickly run SaaS applications on a Morph AppSpace, and move from sign up to deployment within minutes.[23]

Morph is able to use Amazon's on-demand compute and storage resources "to instantly provision an enterprise quality elastic application environment. Each application environment can be enlarged or reduced in real time to meet user needs. This flexibility eliminates the practice of over provisioning the application environment only to service peak periods."

Storage on Demand

Cloud computing or utility computing provides access to computer resources on demand. With computing resources in a cloud, storage also needs to be accessible by flipping a switch. The utility storage concept "conjures the idea that IT resources can be turned on and off to coincide with fluctuating needs just as we control the flow of electricity, water or gas into our homes and offices."[24]

With storage on demand, firms can reduce the chance that they will purchase too much storage. A storage "utility" becomes "storage that is easily provisioned, reallocated, flexible, and retrievable for any platform at any time for any purpose."[25]

Next-Generation Networks

The International Telecommunications Union describes a next-generation network as:

> A packet-based network able to provide Telecommunication services and able to make use of multiple broadband, Quality of Service (QoS)-enabled transport technologies and in which service-related functions are independent from underlying transport-related technologies. It enables unfettered access for users to networks and to competing service providers and/or services of their choice. It supports generalized mobility which will allow consistent and ubiquitous provision of services to users.[26]

In sum, next-generation networks will support not only the transport of data—voice and video—but also service-related functions. These may originate with a telecommunications or a service firm, such as one that provides SaaS.

Many telecommunications and cable operators provide so-called triple-play services that package television, Internet, and voice, part of moving beyond the more traditional voice and data communications offerings of cable operators. Further steps to enhance the telecommunications' and cable operators' abilities to deliver new services are based on service delivery platforms (SDPs) that change the business model of service providers. Rather than growing profits from an expansion of transport networks, these firms are shifting to a new business model that is often called Telco 2.0. In this model, SDPs let service providers "bring more services to market more quickly … generate new revenue through new partners and business models, [benefit from] … personalization and customization of customer features and … offer a broad range of IMS [IP multimedia subsystem]-ready services across networks."[27]

Current networks with SDPs will move a large part of the distance to next-generation networks. But the networks of the future will need several other characteristics that illustrate their differences with enhanced networks that offer video to consumers today. These characteristics will make it possible to more easily integrate service delivery in communications networks. Among them are "decoupling of service provision from transport; support for a wide range of services based on service building blocks; broadband capabilities with end-to-end QoS; interworking with legacy networks via open interfaces; [and] … unrestricted access by users to different service providers."[28]

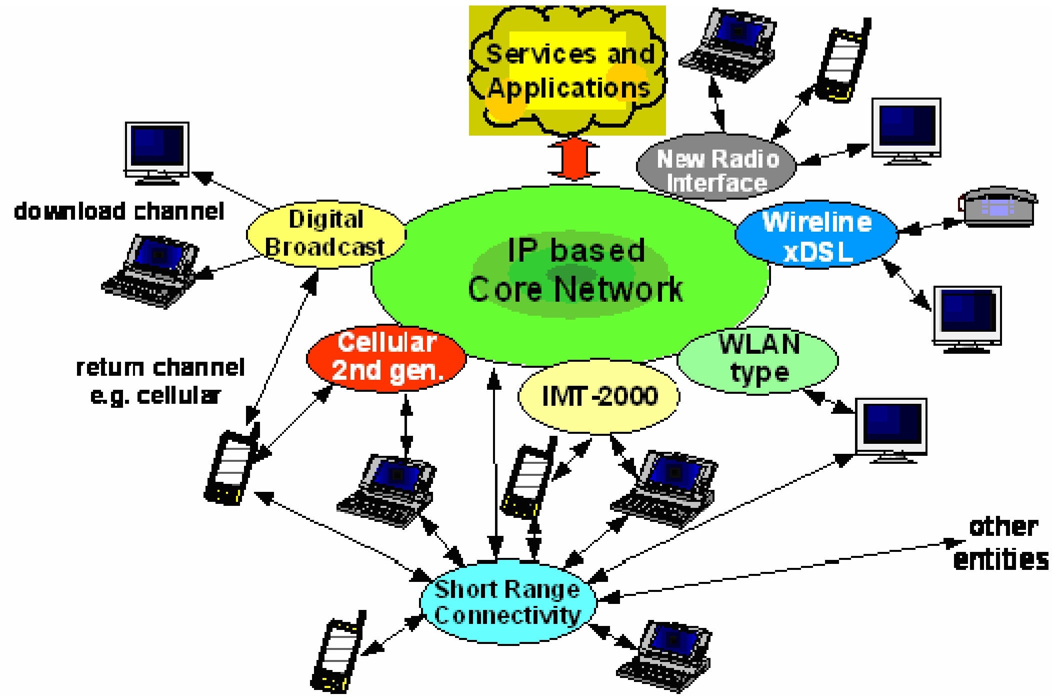

Figure 4. A next-generation network with extensive mobile connectivity. Source: Carugi, M., *What is NGN: Service Enablers.* International Telecommunications Union, /Open Grid Forum Workshop on Next Generation Networks and Grids, Geneva. Oct. 23–24, 2006, p. 22. http://www.itu.int/ITU-T/worksem/grid/presentations/s2p2-carugi.pdf. Accessed Oct. 8, 2008.

Two characteristics of next-generation networks are central for innovative use of Virtual Worlds and cluster computing. First, firms will be able to obtain a wide range of services from any firm they connect to, such as research applications for testing a new design. Second, firms will be able to set up computing resources within clouds and control the bandwidth needed to integrate computing and data resources. In addition, any location in the world will be able to link to one enterprise's global innovation network. These capabilities will make it easier to coordinate and control R&D for product design and testing by not restricting these activities to the place a firm or partner is located. They should also permit enterprises to obtain many of the efficiencies that are expected of well-run global research firms. Virtual Worlds will become centerpieces for collaboration within and between corporations.

The Socially Networked Corporation and Collaboration

This section discusses how Virtual Worlds connect innovations in three areas of technology in ways that alter how businesses collaborate. Virtual Worlds will serve as the new "brain" or "glue" of the enterprise. With this center for intelligence in place, corporations will restructure hierarchical systems to create new ways to manage business operations and make strategic decisions.

There will be a shift in focus from process and structure to innovation and networking. In the innovation- and networking-oriented corporation, much greater attention will be paid to creativity, social networking, and social groups. The groups will provide new ideas about how to organize to create product designs and how to capture information from consumers to respond to market needs.[29]

One good example of working with social groups is the work Cigna has done in healthcare. Cigna's subsidiary, vielife, has used Second Life to support a program to prevent illness. Working with groups of people who have specific illnesses, vielife has organized focus-group–like sessions in Second Life to discuss how to live with a severe illness, such as HIV. The group is screened by vielife to insure that only registered participants attend, but the use of avatars makes it easier for many in the group to be more candid in the discussion of how they deal with their condition. The site is a "virtual extension" of vielife's health coaching service that supplements online and in-person sessions. The "virtual health consultations help foster real and sustainable behavior changes that improve health."[30]

Another consequence of Virtual Worlds may be that control of daily operations will shift to the corporation's internal social network, and higher levels of management will integrate this control into complex strategic and business goals. Because work groups have much greater responsibility for product development and marketing, this could flatten the corporate hierarchy. It might also make large corporations more agile and responsive to new trends.

Social networking changes the corporation in several ways. It provides more leverage and decision-making power to groups that are responsible for product development, product design, and marketing. These groups will determine how businesses collaborate within the firm and with key suppliers and partners outside the firm, as well as with customers and potential customers and suppliers. In a wider context, Virtual Worlds and the interconnected technologies will change not only collaboration but also the way that businesses use information technology (IT) infrastructure.

IT resources would be used to build business from the bottom up, rather than reinforcing the hierarchical management structure of the modern corporation. In a sense, social networking's inherent flexibility in linking different individuals in myriad ways provides the firm with the ability to reconfigure human beings into new types of work teams that can merge to deliver a service or product. In other words, social networking software creates a new flexible infrastructure that firms can use to reconfigure themselves to respond to external or internal requirements. In creating such flexible teams, the corporation will need to organize and prioritize conflicting demands for itself and individual employees. Although there have been attempts to decentralize corporate management structures, such as matrix management, no structural reform has been able to integrate contributions from the bottom up the way that Internet-based social networking does. The development of tools that work against hierarchies may prove central to changing how businesses operate and how they use information technology.

We assert that social networking can lead to a new work environment where inputs for product development, design process, production, or value chains can be gathered from diverse participants. This creates a new, decentralized corporate management system that focuses more on coordinating and managing socially networked contributions in a structure that is open to change and adjustment. Several corporations are already doing this:

> [At] Hewlett-Packard, 50 executives log into their individual blogs each morning to join the ongoing online conversation about each of their product lines, immediately responding to customer problems and concerns. ... Del Monte Pet Foods uses a private online community to regularly “chat” with 400 pet lovers whose opinions help shape new products.[31]

Some of the trends we are forecasting are not very evident, particularly in the area of Virtual Worlds, where most current activity has been in gaming or social networking, which is used mainly by teens, preteens, and 20- to 30-year-olds. As more businesses start to see the virtue of using Virtual Worlds for training and meetings, they will learn about their application in other aspects of their work.

As businesses experiment, for instance, running the complex tests used to evaluate new auto designs or evaluating alternative investment strategies in 3D space, they will see firsthand the important benefits of using Virtual Worlds.

One clear benefit is the ability to do things that were previously nearly impossible. For instance, moving complex tasks into the new 3D Virtual World will permit interconnected groups to draw on the confluence of applications and computing technologies that have developed over the last 5 years or more. The main requirement for dealing with complex tests and designs in Virtual Worlds will be the ability to access immense computing and data storage resources. If a bank wants to analyze complex investment scenarios in a short amount of time, it may need to use 100,000 or more central processing units (CPUs). Scaling up to this capability is now possible due to the vast compute farms that Google, Amazon, Sun, and others have built and offer as virtualized resources. Taking these resources into Virtual Worlds will require some changes in the browser or plug-in–based clients or very “fat” clients like Second Life if users require very complex depictions of the results of simulations. But it is also possible that complex and resource-intensive simulations could be displayed within Virtual Worlds using applications that employ simple 3D images.

With such capabilities, an oil company could simulate how a refinery operates or analyze seismic results using a worldwide group of internal data visualization experts. An auto company would be able to bring together geographically dispersed design and engineering groups to examine the same subsystem of a new model car and then run simulations on its crashworthiness or ability to meet new environmental requirements. Firms might also bring traditional applications into Virtual Worlds and tap into data and computer power they already have at their disposal. The resources available in Virtual Worlds would power such efforts. Gaining access to vast compute resources is now possible because they can be virtualized and assembled in clouds and accessed using Service-Oriented Architectures (SOAs), giving users the ability to harness heterogeneous groups of computing power.

Using the above examples, in addition to the massive compute power required, business process participants in Virtual Worlds would need access to large amounts of data that would describe oil exploration results; financial market information, such as pricing and volumes traded; and other detailed compilations. This, too, is easier to accomplish in a Virtual World, which can access virtualized data stores. The task for Virtual Worlds is to support data in applications used by "in-world" enterprises. This is likely to require better links between traditional Internet-based or real-world storage sources and applications that businesses want to run in Virtual Worlds.

Since accessing compute power and data stores from the more robust Virtual Worlds of the future will probably require high-speed connectivity and even an enhanced ability to manage communications networks, next-generation optical networks are likely to emerge as another key component of future Virtual Worlds. Users who handle large amounts of data and rely on substantial computing power will need large amounts of bandwidth to access these resources. In addition, they will probably require greater control over the networks they use so that they can increase the available amount of bandwidth on demand and move a 512-megabit-per-second network to a gigabit-per-second network. This can be done using controls over the optical backplane, as researchers have demonstrated a number of times over the past few years. To do more sensitive calculations in Virtual Worlds, business users may also demand control over security protocols, quality-of-service settings, encryption, and routing of information.[32] Next-generation networks should make this possible.

New Technologies and How They Transform the Old Model of Computing

The traditional corporate model of computing provides its own resources, has its own IT department, and often develops its own applications or software, particularly when it is using applications that are dedicated to one line of business. This means that, although many businesses don't believe they have a comparative advantage in running IT operations, they must manage one to keep up with their competitors.

In the new model of Virtual Worlds, the recent SaaS—Software as a Service—model means firms can obtain computing and data storage resources on demand. A firm will not have to spend money on software, computers, or data-storage facilities because it will access them using the new 3D Internet of Virtual Worlds.

This would change the economics of using IT resources. They would become a utility like SaaS, with an important distinction. The enterprise would not just access software or applications on demand. It would outsource all parts of its current IT infrastructure, including computing, data storage, and networking.[33] It would rely on cloud computing to access compute resources remotely and on demand. It would do the same for data resources and for the networks used to access compute and data resources.

One thing that would be different is that Virtual Worlds or Web 3D will be the access point to these resources and the organizing glue for the enterprise's operations. Working in Virtual Worlds, or in the 3D Web, would provide a new way for the firm to operate.

Virtual Worlds would bring collaboration to the fore. While it can be difficult for disparate work groups in a firm to collaborate, Virtual Worlds would create secure sites where teams within a firm or teams combining expertise from a number of firms might work together. This would mean that experts at different locations could focus on a single task, such as creating a new product, testing new designs, or fleshing out a marketing campaign.

The ease of collaborating would improve corporate operations in several ways. First, appropriate levels of expertise—possibly from other parts of the firm or from suppliers and partners—will be incorporated in work. Second, the creation and development of intermediate products that internal or external suppliers contribute could be done collaboratively, saving much time and cost by using the secure Virtual Worlds workspace. Third, a much greater ability to refine and test intermediate- or supplier-contributed products should be possible through Virtual World–enabled secure simulation testing. Different suppliers could demonstrate their results to a firm's designers or engineers who are assembling the final product. This would avoid the need for translation or optimization software.

By enhancing and strengthening design and development operations, Virtual Worlds have the potential to enhance levels of competence, which could reduce the need for close management and time-consuming controls over various business segments. In fact, by providing for improved collaboration, Virtual Worlds might strengthen design and development operations and improve firms' economic performance. This could lead firms to respond more rapidly to changes in customer preferences or to regulatory requirements as well as to incorporate enhancements that would save money or improve product quality.

In essence, by mirroring the gains that social networking makes possible and by incorporating a social networking–like structure within parts of the corporation, Virtual Worlds can significantly change the behavior of modern firms.

If collaboration and responsiveness occur in an ongoing manner in corporate groups responsible for design and product development, there would be less need for higher level management to oversee product evolution. This should mean that as the corporation moves forward, it would need fewer people to ensure that product evolution and change occur. The result should be a flatter firm with fewer managers devoted to managing key functions.

These changes in the corporation illustrate what might happen if collaboration operates very differently than it has in the past. Next, we explore specific examples of how Virtual Worlds and on-demand or grid computing might change important business processes.

Changed Role of Collaboration

This section reviews how Virtual Worlds and on-demand computing are likely to impact and change the role of collaboration in industrial competitiveness. On-demand computing has advanced just-in-time and lean-manufacturing principles with regard to upstream design, development, and decision making. It also leads to the creation of new just-in-time services, such as in the financial sector. On-demand computing leverages simulation and testing processes for final products and services. Virtual Worlds and on-demand computing can attract customers and suppliers early in the design and development phase and lead to continuous improvement and innovation, as long as businesses respond to the challenge of managing a network of suppliers in a Virtual World and an on-demand computing environment.

Design and Development

Virtual Worlds and on-demand computing will streamline manufacturing and improve design and development processes. They will also alter the way businesses interact with clients and suppliers by implementing a social networking structure within the modern corporation that integrates customers, suppliers, and internal work groups in all aspects of business—from product development and design to marketing.

The Deming Model for lean manufacturing uses a "Human Design Model to achieve customer satisfaction,"[34] which, in its ideal state, would produce goods on demand or "only what a customer wants." It would also "deliver products defect free from one process to another." In addition, there would be "single-piece flow," where firms build one product at a time. "All waste in the system is eliminated," according to the model, with no need for load leveling. Finally, there would be "open and immediate communication between supplier and customer, both internal and external."[35]

Virtual Worlds and on-demand computing enhance this model in a number of ways. They provide for continual feedback between suppliers and customers, both in workgroups within a firm and in the supply group. This enhances quality—Deming's main point—because it reduces variability in the product, and, in doing so, eliminates waste. The process involves frequent, low-cost meetings and interactions among employees creating a design and other workers in the same firm or in supplier firms. In addition, Virtual Worlds offer the ability to examine a design and focus on issues that customers may raise or that collaborators in the firm or in supplier firms may be concerned about. These issues can be resolved collaboratively as teams of employees visualize the product and test changes in a design or in the way the product performs, as well as show these changes and tests to others while they are being run. This results in what might be called collaborative development, whereby the need for feedback among groups involved in the development process is an inherent part of product development and design. Collaborative development also reflects the points made by James Womack that waste, in terms of "any excess interruption, misalignment, unnecessary work, or ingrained redundancies that add no value for customers,"[36] needs to be removed from the production process.

In addition, because refinements in a product can be added as different groups envision a need for them, Virtual World on-demand computing reinforces the importance of delivering defect-free products and reducing waste in the system. The production process becomes one that is nearly a "single-piece flow" because each item in the flow is customized for the buyer who demands it.

Also, the Virtual World on-demand computing framework brings changes in the way corporations operate because it inherently emphasizes innovation and social networking. It aligns design and development processes with teams that would spend more time and place greater emphasis on innovation because they are able to broaden the ideas that they incorporate in these processes and search widely for new ideas and new approaches. This increases the likelihood that designs change more frequently and are innovative and creative.

Just-in-Time Services

A similar improvement would occur in the service industry, particularly when services firms need to create ways to deliver services rapidly, as in the fashion industry, or when more efficient service delivery needs to be refined, as in the financial sector. In fashion, the hope is to create a new workflow. In finance, the expectation is that combining Virtual Worlds and on-demand computing will help financial firms develop new services more quickly and possibly provide new ways for financial firms to analyze investments.

A recent example of a services firm in Virtual Worlds is Fashion Research Institute (FRI). Its mission is to develop "emerging technologies to overhaul traditional fashion practices and methodologies."[37] The goal of the site in Virtual Worlds is to create "a fundamentally new work flow addressing critical issues facing the design industry, such as ensuring manufacturability of designs and decreasing substantial sample costs by two-thirds."[38]

Besides design capabilities, FRI's goal is to let designers take an idea from concept to prototype. The design system will:

> connect to the OpenSim virtual world platform to create packaging and fashion products, provide efficient workflow queues, and allow groups with an interest in the product to collaborate and modify designs. The program will also generate virtual product samples and accurate factory specifications that enable high quality product mass-manufacturing in the real world.[39]

In the financial services, many of the initial efforts in Second Life are quite modest and represent providing information that might be offered on a traditional Web site. ABN·AMRO, for example, is using Second Life to provide a wide range of information about its services for private clients and businesses—and at the same time seeking new ways to interact with its traditional clients.[40] Different floors in its "sim" or virtual island contain detailed documents describing the various types of financial products that customers can access. ABN·AMRO also holds an interactive seminar about current market trends in Virtual Worlds every 2 weeks. In addition, the bank has a Tradeglobe experience that includes podcasts and commercials that can be watched in Second Life.[41] For new entrepreneurs, it has a Technodesk that provides materials about starting up new businesses in information technology or other technical areas. [42] The materials include information about financial help for startups.

While ABN·AMRO has only just begun Second Life operations providing financial and business information, it could use this presence to develop new services. One way to do this would be to take recommendations from private or business customers and use them to develop new financial services. These could be developed using Web 2.0 and Service-Oriented Architectures (SOAs) to provide a platform for the new services and their delivery to users. A Web 2.0 framework might also build on service delivery platforms that telecommunications firms are using to rapidly deliver innovative services.[43]

In addition, banks could use 3D data visualization capabilities to analyze complex information. One large bank, for example, has expressed an interest in being able to see investment strategies depicted in 3D space so that different desks might more clearly envision how bets placed in a range of strategies might work out under different market conditions.[44] If using such a tool could clarify risks and benefits better than examining single models and their likely risks and returns, it might prove to be very valuable.

Simulation and Testing

Several observers have noted that Virtual Worlds would provide a way for companies such as oil industry firms to bring "geophysical and seismic data feeds" into an environment where exploration and production experts could query databases and "do real-time 3D data visualization."[45]

If computing capabilities were accessible from within Virtual Worlds, experts would be able to model and test designs and use simulations and tests to explore the development goals for a new design. This would push collaboration to a more refined level where a multitude of simulations could be run and analyzed by a substantial group of collaborators. In this scenario, the ability to draw on on-demand computing resources and to access large databases would support significant new innovation in product design and development. It would permit those involved with creating a new product to immediately see what works and where improvements are needed. It would also provide a way to link simulations across traditionally "siloed" business groups and connect information about tests and analyses that is often not communicated in a timely manner.

Creating virtual cars is one step that automakers have taken to deal with the challenge of more complex design and product development. European automakers such as Audi, DaimlerChrysler, BMW, and Porsche are using or experimenting with virtual cars, 3D files with data that support collaboration among engineering design groups. The virtual cars permit design engineers to evaluate a range of new designs and to manage the inclusion of crash testing, computational fluid dynamics (CFD), structural testing, and noise-vibration and harshness simulations in the overall model of a car. As Cohen explains:

> The advantages of using "virtual cars" are several. First, firms can go through many more static and dynamic simulations using well-known tools such as LS Dyna, NASTRAN, etc., for crash and CFD analysis. This provides robust results and shortens time-to-market. Second, testing and design costs are reduced because simulations replace much of the work that used to be done in these groups. This not only reduces costs but also cuts down what had been a major area in product development. Third, auto firms are looking for more flexibility in design. They need to be able to respond quickly to new regulations, such as German requirements that the front ends of cars create fewer significant injuries to pedestrians. Virtual cars have let manufacturers change a model design quickly. Fourth, virtual cars have let companies such as Audi greatly increase the number of models they offer. They can design different versions that build on the same frame and often retain other parts of an established design, such as the windows, doors, or trunk. Audi now markets about 40 models compared to about six a decade ago.
>
> To create virtual cars, auto firms have enlarged their grids to more than 1,000 CPUs. They have employed traditional applications as part of their SOAs [service-oriented architectures] and employ many simulation and CAE [computer-aided engineering] applications on SOAs. Having excellent access to needed data, as well as to compute power, is a sine qua non for virtual cars.[46]

Using virtual cars, auto firms can run simulations at one design group and transfer the virtual car and the simulation results to another design group. This requires having substantial bandwidth between different design groups on the same campus and at other locations, usually in the 10-gigabit-per-second to 100-gigabit-per-second range. Some auto firms are developing "dark fiber" networks to provide this connectivity.

An alternative approach would be to work on virtual cars in Virtual Worlds. While no auto firms seem to be doing this, firms such as Cisco and several oil industry giants have been doing or are planning this type of analysis and product design work in Virtual

Worlds. The difference in approaches is that using Virtual Worlds allows different design or work teams to be linked into a single site to see simulation results and the 3D virtual car design. This enhances collaboration between groups and speeds up work on new designs. It can also reduce travel time and the spending on bandwidth that might be needed to connect different locations. Some of the spending on bandwidth might be offset by the need to connect data and computing resources to a Virtual World Sim.

Another benefit would be that suppliers and consumers could see car designs in Virtual Worlds and provide feedback on them before they went through the development process. If this happened, suppliers might point out parts of new designs for which it might be difficult to produce new parts, and consumers might indicate which parts of a design they like and which they dislike.

Boeing used a virtual environment to design the 787 Dreamliner.[47] The environment included a series of virtual tools from Dassault Systems for virtual planning and production, virtual product design, and enterprise-wide collaboration. Every participant in the design process had "access to 3D data models of parts, assemblies and systems. The digital assets developed by Boeing using these [product lifecycle management] PLM solutions will be used across the 787's entire lifecycle, including sales, marketing and future derivative aircraft." In addition:

> Boeing's planning and layout of production lines using exact 3D models of parts and assembly tooling dramatically reduces rework on the 787. Such a digital manufacturing environment creates a communication "loop back" between 787 design and manufacturing engineers, no matter where they are, eliminating the risk of committing to a design change only to discover it cannot be manufactured, or that it requires costly changes to other components.[48]

While Boeing is not using Virtual Worlds, this example illustrates how a major design project can employ 3D design environments, traditional design tools, and a new computing backbone to provide all participants with a role in product design. Wasted time for retooling and redesign is kept to a minimum because of the ongoing communications among the engineers involved. In addition, parts and the tools used to manufacture them are designed at the same time, rather than delaying the creation of the manufacturing environment until after the design has been developed. The time and cost savings, as well as the ability to bring the new design to market quickly, are key benefits.

Greater Collaboration with Customers and Suppliers

There are a number of benefits associated with using an environment that includes Virtual Worlds and on-demand computing for design and development.

Some of the main benefits are tied to data visualization.[49] As noted in the Boeing example above, one benefit is being able to build or import and share digital 3D models. These models can be seen and modified by all participants. They can also be linked to computer-aided design and product lifecycle management systems so that changes in the design are reflected in other parts of an overall system.

This environment also allows users to represent information and data in new ways. With very complex sets of data, customers and suppliers can get to see what is happening and delve into complex details that can be displayed in 3D space. This capability can help people develop better mental pictures of what products look like.

Virtual World environments also help people visualize information in new ways. Financial firms have built stock histograms and pharmaceutical researchers have depicted drugs in 3D space, making it possible for customers and suppliers to understand phenomena and structures much better than they could in 2D space. In addition, collaborations take on a new dimension because participants can get insights into projects more quickly. This benefits design efforts because something that doesn't look right can be corrected earlier in the design and development process.

Continuous Improvement and Innovation

A recent study by IBM and Seriosity sees the future of business management in massively multiplayer online role-playing games (MMORPGs). According to this report, business will be more "open, virtual, knowledge-driven."[50] The report notes that:

> gaming leaders are more comfortable with risk, accepting failure, and the resulting iterative improvement, as part of their reality. Many of these leaders are able to make sense of disparate and constantly changing data, translating it all into a compelling vision. And the relationship skills of the best gaming leaders would put many Fortune 500 managers to shame.[51]

Online games, which represent a large part of Virtual Worlds, also encourage risk taking. Given this and the other characteristics of game participants, business management experts believe that the new management style emerging out of games has a number of significant advantages over traditional leadership development.

In essence, gaming helps promote innovation because, as Baxter notes, "the freedom to fail and the encouragement of risk taking, which can spur innovation, are further features of both MMORPGs and some Second Life activities, such as Insead's business development competitions."[52] In fact:

> Second Life, says the [IBM–Seriosity] study, reinforces the same sensemaking and visioning skills that games such as Eve Online instill. This game, it says, explicitly reinforces the ability of a leader to go beyond how a task will be completed and instead focuses on what kind of task is best in the first place. In Second Life, doing well—defined as designing activities and building structures and artifacts that others want to use or purchase—requires having a larger vision in addition to an executional plan.[53]

These findings indicate that Virtual Worlds may help create a new type of management that is more concerned with innovation and the continual improvements of products than traditional management has been. Gamers have gained these new skills because the processing power and access to data in Virtual Worlds have fostered an environment in which far more time can be devoted to risk taking and in which failure is part of the overall experience, not a black mark that follows leaders throughout their careers.

Challenges of Managing the Supplier Network

A recent SRI International analysis noted that businesses were beginning to "recognize the role Virtual Worlds can play in collaborative work."[54] It noted that Virtual Worlds "can enhance social connections and networking" and "help build trust among distributed and disconnected team members." It also found that Virtual Worlds can "improve certain work processes by easily and quickly bringing people together to visualize information and collaborate on certain tasks."

This analysis suggests that Virtual Worlds, as well as the on-demand computing and data resources they can be linked to, will make it easier to integrate suppliers (as well as widespread in-house contributors) into an organization. This advantage is likely to be based on the networking and collaboration that are central to working in Virtual Worlds. It is also important that the immersive environment provides a new way to visualize data in 3D as a group and to work on tasks.

These characteristics of Virtual Worlds differ from traditional work environments. They stress group work over isolated tasks and provide a new context—3D visualization—that offers unique insights not possible in traditional visualization. This seems to have the potential to meld suppliers and final producers together more closely.

Broader Implications

Virtual Worlds and on-demand computing have a real potential to reduce time to market and the time it takes to perform critical business processes.[55] The new immersive environment, aided by easy access to large computing resources and data stores, facilitates the analysis of complex designs and models far faster than is usually the case in business. We are already beginning to see the effect of this in early business adoption of Virtual Worlds because design- and decision-intensive industries, such as architecture and media and entertainment, have been among the early adopters.[56]

It appears likely that Virtual Worlds will change the skills of employees and managers and place greater weight on just-in-time and time-critical business processes. If this new environment enhances such capabilities, businesses may be better able to face challenges that require new skills that are suited to design- and decision-intensive services and manufacturing.

This could result in more knowledge-intensive industries growing in areas where these skills are very available. It also suggests that remuneration of firms and individuals for this type of work could become a significant engine for economic expansion in the future.

Transforming Industrial Structure and Function

This section discusses how Virtual Worlds and on-demand computing will begin to transform industrial structure and function. To support more sophisticated applications, firms that use Virtual Worlds for product design and development or service innovation and delivery are likely to require large amounts of readily accessible computing power and data storage.[57] In a sense, this will mean that people and businesses will use computers or remotely accessed computing resources very differently than they have in the past. Computers will be used to collaborate in Virtual Worlds with others in the same firm or in firms that are suppliers of intermediate or final goods or services producers. The increased computational power at employees' fingertips will also mean that problems that could previously only be analyzed with far more substantial computing power will now be able to be analyzed as part of everyday work processes. Businesses will be able to perform much better analyses of designs, marketing plans, and financial investments. Virtual Worlds will also allow companies to bring the customer into the design and development process and to participate in analyzing the performance of products after they are purchased. Sophisticated decision making will become more common, although firms may face major adjustment and transformational issues that provide challenges for management.

Increasing Computing Sophistication

Intel's vision of this future imagines that computers with hundreds of integrated processors "will empower tomorrow's technology with more human-like capabilities. Computers will be able to 'think' in terms of models—digital 'concepts' of people, places, and things found within streams of bits and bytes—enabling them to do far more sophisticated work for users."[58] Processes that are amenable to being analyzed by models, such as designing a car or determining the best way to invest in a volatile market, are suitable for the kind of model-based computing that Intel envisions. When more than one person is doing this analysis, it will be increasingly likely they will employ a Virtual Worlds platform to run the simulations and analyses using 3D data visualization.

Many experts already recognize that to realize a true 3D Internet, far greater computing power will be required as enterprises and consumers turn to more complex Virtual World applications. Justin Rattner, Intel's chief technology officer, has estimated that the sophisticated Virtual World applications expected to be in use over the next few years are likely to require the following components:

- Servers—10 to 100 times more computational power than that required by more traditional online games.
- Clients—Three or more times the CPU power and at least 20 times the graphics processing power.
- Networks—At least 100 times the bandwidth required by more traditional applications.[59]

Intel's vision of the future is not the only one that imagines huge networks of servers and storage devices employed for multiplayer gaming being adopted for business applications. Forterra developed its Virtual World platform, OLIVE, for simulations "to easily scale from single user applications to large scale simulated environments supporting many thousands of concurrent users. Working with the OLIVE platform, customers can create realistic Virtual World content and plug-in functionality to meet a wide range of simulation needs. An API layer enables customers to reuse existing content, integrate with third party applications, and leverage third party tools."[60] Forterra's business focus is on creating enterprise applications and applications for professional use.

Firms such as Dassault Systems that sell software that enterprises use to design complex products indicate one path for a transition from machine-based applications to Virtual Worlds. Dassault has recently introduced tools that begin to make a transition from 3D computer images to a more virtual reality. Its new tool, 3DVIA, creates a realistic 3D environment for auto parts designed using its traditional CATIA program. This is part of Dassault's effort to develop tools that support collaborative business process from 2005 to 2010 and to create "realistic simulations" from 2010 onwards.[61] Dassault's Virtools provide a way for designers to imagine what their products might look like in 3D. These tools appear to underscore Dassault's intention to transition from traditional desktop-based imaging and virtual reality using special 3D displays into Virtual Worlds.

A second step in moving to Virtual Worlds will be to change the dedicated computing resource model that many firms rely upon. Some companies are building internal clouds to create an environment in which they can flexibly access computing as well as data storage resources. Merrill Lynch is currently building a shared utility computing model that will permit its employees to combine storage "capacity dynamically with operating system and application components to meet its computing needs in real time."[62] This is a utility-computing, cloud-computing, or stateless computing model that makes "access to all applications ubiquitous by placing them in an organized file system or namespace much like the World Wide Web is a namespace."[63] Large banks are building such cloud-computing environments today because these environments have faster internal networks; because they have less need for redundant hardware (both for computers and storage devices), allowing the firms to cut costs; and because of the rise of cloud computing in general.

Cloud computing can also be employed when firms want to outsource or externalize their access to computing resources. In many cases, cloud computing's early users have been smaller companies in businesses where consumer demand can change dramatically from one day to the next, and in which it's important that the company not run short of capacity (a real possibility for companies relying on their own computing facilities, which can be costly to build and maintain). Amazon customer Digitaria, a Web development firm, did not want to rely on its own computing resources to support its business because of the volatility of traffic coming to certain Web sites it supports. It instead chose Amazon's "Elastic Compute Cloud (Amazon EC2) to help them deliver scalable, cost-effective"[64] compute resources.

Result of More Intensive Users

If industries that use Virtual Worlds can access more computing power and software, they can broaden the ways that computers are used within business organizations. Computing-intensive business problems will be addressed because far greater computing power and more sophisticated software will be available. In addition, collaborative groups in Virtual Worlds could address these problems together, bringing a wider range of expertise together to focus on difficult problems. Today, many of these business issues may not be addressed because the computing power and software a firm can use to address them are inadequate for modeling the situation. Even industries that currently bring large numbers of servers to focus on issues related to financial investments, auto design, drug development, and aerospace design are not using computing resources that are as sophisticated as they will be in a few years. Once Virtual Worlds become more widespread and focus on a range of traditional business processes, immersive environments could enable teams based around the world to model behavior in the manner suggested by Intel. Even traditional areas, such as bookkeeping, might draw upon the power of on-demand computing to model the way business payments are handled and design new ways to run the traditional back office more efficiently.

More sophisticated software might make it possible to develop more complex product lifecycle management (PLM) tools to synchronize contributions to a complex design process. [65] While many auto firms have design groups that perform tens of thousands of simulations to test new model designs, they lack the PLM tools to orchestrate the complex process of design between large numbers of suppliers and the final manufacturer. With sophisticated software and much greater levels of computing power, PLM tools might integrate design and development steps across a wide range of firms that contribute different products to an extremely complex design and testing environment. There is some evidence that Boeing has developed such tools, especially tools for "digital prototyping,"[66] in collaboration with Dassault Systems and that they were crucial in the rapid design and development of the Boeing 787.[67] In contrast, the Airbus 380 ran into problems with its product lifecycle management.

With on-demand or utility computing, firms would be able to use more flexible computing and storage resources. These resources would scale to any size as soon as they were needed. This capability would open the way for businesses to use more complex computing to solve R&D, design, and testing problems or to establish large data stores to back up Web sites or large projects, regardless of whether they are short-term or more permanent.

One place where this is already happening is in the design of "virtual cars."[68] Auto firms have enlarged their grids to more than 1,000 CPUs and can now run many traditional applications on these grids. Firms are using high-speed communications networks on local campuses and between facilities to let engineers collaborate in the design of a virtual car, which now is a file at the 10-terabit level. Today, design engineers at Audi in Ingolstadt, Germany, work with their counterparts at SEAT in Martorell, Spain, on the same virtual car. Berco, an engineering group that supplies designs for undercarriage parts, may soon be linked to the Audi network to collaborate in engineering design. Doing so would save considerable funds compared with using traditional approaches to set up computing resources for a business group or corporation. In general, hardware, software, and storage spending might cover only part of what a business required because much computing could be done through a utility-oriented service.

Effect on Industrial Structure

Since Virtual Worlds open collaborative environments to many more participants, they should broaden collaboration within and between corporations. This raises an interesting issue. If Virtual Worlds enhance the ability to coordinate and control rather complex corporate operations, might they not also expand the scope of management? Alfred Chandler demonstrated that modern corporations were shaped by crises resulting from management's inability to oversee far-flung operations.[69] With substantially more compute power to coordinate and analyze complexity, the scope for management might be expanded.

This would certainly apply to complex products and services and, especially, to those where there is a great deal of innovation in product and services design. However, it might also equally apply to simpler repetitive products and services where there is very little change if collaboration with suppliers and marketing operations were made easier. If, for instance, sock producers found that it was easier to collaborate with retailers as long as confidential inventory information was shielded, they might elect to use Virtual Worlds. Such technology might improve businesses that some would have assumed were not likely to switch from an old-fashioned hierarchical command-and-control model.

If management improvements—particularly a greater ability to oversee and coordinate complex processes—occur with Virtual Worlds, there could be important changes in industrial structure. For instance, "multi-industry" conglomerates could emerge and be characterized by greater vertical and horizontal integration. In this shift, corporations would bring important parts of supplier networks inside their own corporate structure. This would link the innovation and creativity of outside suppliers more closely to product development and testing.

This broadens the range of design and development skills inside the corporation and also gives firms the ability to apply such skills outside their traditional sectoral limits, resulting in what we might call multi-industry conglomerates, which span more industries than conglomerates do today. Examples of such conglomerates might emerge if aerospace and auto firms merged and brought along large parts suppliers or tool developers, such as Dassault Systems. Another possibility would be for companies that develop parts and components for a range of industries—auto, aerospace, electronics, and computing—to merge into a single entity. Flextronics, which now manages a wide range of production facilities for the semiconductor industry, many of which were merged together by Solectron, suggests that organizations could move in this direction.

These multi-industry conglomerates might be feasible in a number of other industries as well. Small pharmaceuticals firms, which develop new processes because they are very innovative and agile, could be brought under the wing of a large pharmaceutical company in rapid fashion. Bringing such innovators under the corporate umbrella much earlier than is common today would only be possible if Virtual Worlds allow a larger firm to manage the intellectual property and innovative processes of the smaller firm brought under its wing. The smaller firm might also need to use Virtual Worlds to find better ways to exploit its contributions to the larger firm.

A second trend that could contrast with the one above would be a move to a modern "guild system," which would be a way to more explicitly maintain suppliers' independence.[70] These suppliers might be able to use Virtual Worlds to create products for a much wider range of final producers than they have traditionally served. This shift could be due to their ability to more readily contribute to product design and development activities in a wide range of firms as well as capture accurate information about consumers. For these reasons, they might have a strong economic case for asserting their independence. In a similar way, specialized financial firms, such as investment funds, might be able to help create unusual investment strategies for a range of financial giants, hedge funds, or investment vehicles, also giving these firms a rationale for maintaining independence.

This could result in a "serially linked relationship" industrial structure, with numerous independent innovative supplier firms or partner firms connecting with other firms that value their inputs or services highly. This modern guild system for more specialized enterprises would include firms with extremely refined areas of expertise that can shop their services or wares to a range of corporations in both manufacturing and service, but are linked to a larger innovative whole within the Virtual World. For instance, the pharmaceutical industry relies on a wide range of clinical research organizations (CROs) to conduct new drug trials. Much of the results of these trials are fed into a specific pharmaceutical company's group overseeing a specific trial. With Virtual Worlds, such trial results could easily be viewed several times a day and the participants from the pharmaceutical company and the CRO could be in more constant communication.

For modern guild system firms, access to Virtual Worlds, to on-demand computing, and to a number of different partner firms with compute, data storage, and other resources that could easily be shared among suppliers could make providing services to a wide range of partners much easier. The benefit for corporations that are linked to specialized enterprises is that the modern guild system firms could use model-based computing, collaboration in Virtual Worlds, and better integration of firm experts to improve their own services and innovative character. Contributing innovations individually or even in concert with other guild system members could be a different way to accomplish this.

One major difference between modern guild system firms and the multi-industry conglomerates would be the ability of guild system firms to gain better market inputs from the widespread and talented pool of companies and individuals included in the network. The larger conglomerates could include many suppliers and a wider range of industries, but they might not be able to exploit the benefits of social networking and consumer reactions to product ideas and designs as well as the modern guild system firms. Many of the firms in the modern guild system group would be more agile and innovative and easily incorporate the latest engineering and computing developments. One factor that has always slowed change in bigger firms, such as large pharmaceutical companies, has been the need to wait for nearly a generation to overcome trend-setting shifts, such as the change from wet-lab research to computer-based analysis. Modern guild system firms would tend to recognize such shifts immediately and quickly adapt new technologies.

The multi-industry conglomerate response reflects some of the ways that observers believe Virtual Worlds or utility computing may change business. One analysis noted that cloud computing and more sophisticated software will make IT resources “highly responsive and business goal driven.”[71] Nicholas Carr believes the rise of electrical utilities may be similar to what will happen with on-demand computing; that is, as electricity becomes available on demand, a consolidation of resources into a few large companies will ensue. This would change the nature of the IT business dramatically, moving it away from the hardware and software industry we know today.[72] We see this move to vertical integration as one main trend, where some sectors become “super” vertically integrated.

On the other hand, if the benefits of collaboration and social networking enhance the ability of smaller firms to innovate and expand their expertise, then the modern guild system firms might also be very viable. Their success may stem from their ability to handle “soft skills,” such as personal interactions, far better than traditional corporations that operate outside of Virtual Worlds.

Open Versus Proprietary Systems

What types of Virtual World platforms, grids, computing ecosytems, and next-generation Internet are required to bring about the changes discussed above? The answer to this question revolves around the issue of open versus proprietary systems.

There is concern that because today’s computing depends more on others’ infrastructure, whether for Virtual Worlds, cloud computing, or SaaS, that “being a developer on someone’s platform will mean being hosted on their infrastructure.”[73] Tim O’Reilly opines that:

> [P]latform as a service plays, from Amazon’s S3 and EC2 and Google’s AppEngine to Salesforce’s force.com—not to mention Facebook’s social networking platform—have a lot more in common with AOL [America Online] than they do with Internet services as we’ve known them over the past decade and a half. Will we have to spend a decade backtracking from centralized approaches? The interoperable Internet should be the platform, not any one vendor’s private preserve.[74]

The solution to maintaining this openness could take a number of directions. One, suggested by O'Reilly, would be to build on "the lesson of open source and the Internet … that we can build an operating system that is designed from the ground up as 'small pieces loosely joined,' with an architecture that makes it easy for anyone to participate in building the value of the system."[75]

This, he asserts, could be a way to get around the concern that only a few corporations stand to gain the most from the broad adoption of cloud computing and SaaS. The concern stems from a worry that firms using these technologies can exploit the many contributors who get paid very little to make these platforms successful. This could lead to a kind of "digital sharecropping," which Nicholas Carr has criticized.[76] Carr and others who disapprove of these developments believe that unless the dominance of application programming interfaces (APIs) and control of data centers is broken, the new Internet and computing world will be dominated by Amazon, Google, and Salesforce.com, much like the way Microsoft dominates the personal computer market.

A different approach would be to create an open standards[77] Internet operating system that would tie together applications that use Virtual Worlds, cloud computing, and SaaS, making it possible to "build on services that are designed to be federated rather than centralized."[78] This approach would address Carr's digital sharecropping concerns by giving the little players equal access to the Virtual World field.

But if we turn Carr's thinking around and apply the electrical utility analogy to cloud computing,[79] we get a system where open standards[80] would permit the Internet and cloud computing to provide for greater value added by producers of services and goods that would not be controlled by today's IT service utilities. This results in a very different way to view the outcomes in the new Internet and SaaS world. In this "anti-Carr" view, IT service utilities would not dominate the future of computing and the Internet. Instead, they would become the "utilities" for platforms of the future that are much more open. This result would require an effort to limit the ability of the "electrical utilities" to become national monopolies. One step toward this is congruent with Tim O'Reilly's writings.[81] O'Reilly foresees the creation of a new Internet operating system that is the hub for a wide range of applications that developers create, relying on cloud computing, SaaS, and, by extension, Virtual Worlds. Another step might be to limit the scale of utilities that support the future Web 3D, cloud computing, data storage, and networking conglomeration of technologies. This might require national or state ownership of some resources so that these firms would resemble a utility rather than a monopoly.[82]

Increasing Firm Efficiencies[83]

There are significant efficiencies that firms have gained by adopting grid computing. Virtual Worlds and on-demand computing will build on these efficiencies, creating environments where businesses can address more complex product development challenges. We can already see efforts to promote collaboration in the push by Intel, IBM, Nokia, and other firms with large numbers of designers to get their design groups to use a collaborative environment. This will permit designers in different locations to work as a single team. Collaboration also helps reduce time to get new products to market.

Auto and aerospace firms have made real progress using commercial SOA products, tools, and grids. They have created "virtual cars" and "virtual planes," 3D files with data that facilitate collaboration among engineering design groups.[84] By using virtual cars, engineers can test designs and manage crash testing, conduct computational fluid dynamics (CFD) analyses, test structures, and evaluate noise vibrations as they design new car models.

There are several advantages to "virtual cars."[85] First, firms can go through many more static and dynamic simulations using well-known computer-based simulation tools, such as LS Dyna, NASTRAN, etc., for crash and CFD analyses. For the final design, this means much more rigorous testing and analysis, shortening the time needed to bring a new design to market. Second, such simulation work can reduce the cost of the testing and design processes by automating processes that might have been done with models and wind tunnels or using physical crash testing. This reduces costs and the time to evaluate a new product. Third, auto firms are seeking more flexible designs. For instance, if a new government regulation is promulgated, automakers want to respond quickly and not put off the introduction of a new design just because the rules have changed. Computer-based simulations allow them to respond quickly to new regulations, such as a new German requirement that the front ends of cars create fewer significant injuries to pedestrians. Virtual cars let manufacturers change a model design quickly. Fourth, virtual cars have let companies like Audi greatly increase the number of models they offer. They can design different versions that build on the same frame and often retain other parts of an established design, such as the windows, doors, or trunk. Audi now markets about 40 models compared with about six a decade ago.[86]

Virtual cars could well be the tool that expands the use of grids. If auto firms can use virtual cars and aerospace firms begin to rely on virtual planes,[87] the way they collaborate with their suppliers may suggest solutions for other firms that rely on suppliers for innovative designs. For instance, semiconductor design firms, such as Intel and IBM, or pharmaceutical firms doing drug design work could create 3D models that groups throughout the world can contribute to. Thus, virtual cars could push grids to a new frontier—the "collaboration grid." With collaboration grids, different simulation and design groups could operate as a single team whether their facilities are separated on a corporate campus or by miles of land or ocean.

If such collaboration grids are widely used in the automotive and aerospace industries, they suggest that the traditional Grid 2.0 model is insufficient because it contains conceptual gaps. In traditional Grid 2.0 thinking, grids never move beyond the enterprise. Collaboration grids could encompass vast components of the firm as well as a large number of suppliers, subcontractors, and engineering partners that the final firm—the automaker or the aerospace enterprise—does not own in the classic sense.

Auto firms' use of collaboration grids shows they want to go beyond "virtualization, aggregation and sharing of all compute, storage, network and data resources."[88] Rather, they see SOAs and grids transforming the way they bring new products to market, shifting from a technology focus to a market or a business focus. And this is where SOAs and grids provide real power—enabling the savviest auto firms to leave their competitors in the dust when it comes to profits and creating cars that are extremely responsive to customer needs.

While much of the recent news in SOAs and grids revolves around SaaS, advances in the virtual car show that grids are contributing to a major shift in the way complex machines are produced. If collaboration grids are used across a range of industries, they could alter how firms engage in engineering design. Even service firms might benefit from the creation of a new tool that shortens the time to design and deliver new services.

Virtual products—not only the virtualization of resources—could help change the way modern corporations operate.

Transforming New Industries

Grid computing and on-demand computing have the potential to transform existing corporations, leading to an entirely new business sector made up of "fourth-wave" industries. This terminology is based on the fact that agriculture represents primary industry, manufacturing represents secondary industry, and services represent tertiary industry. In the fourth type of industry, firms are built on computer-related technologies that can handle the extreme complexities of their business enterprises and accommodate the extensive partnerships required to develop new products and services.

Fourth-wave industries are likely to differ from other industries in that all of the products or services they create will be designed, developed, marketed, and managed after sale with the use of Virtual Worlds, cloud computing, virtual data storage, and next-generation networks. The products of these industries are likely to be created by a collaborative web of firms that are tied together through design and product development and composed of work teams that rely on Virtual Worlds linked to clouds and scalable storage.

Stem cell industries, which are often more broadly defined as part of regenerative medicine industries, could be pioneering fourth-wave firms that would benefit from extensive use of Virtual Worlds, cloud computing, and virtual storage. The creation and design of new stem cells requires working closely with partners to design individual stem cell lines. Once this is accomplished, the stem cell firm and its partners will need to produce large numbers of stem cells from specific lines using bioreactors. For each stem cell line, the firm and its partners must accurately preserve and document its genetic composition and the characteristics of any lines that are derived from it. They must also document and authenticate intellectual property rights, stem cell lineages, and the reactive histories of each stem line. Stem cell partners and collaborators will want to develop derivative variations of the basic cell lines and provide rapid access to this information. Firms must track genetic data unique to each stem cell line and its cohort and manage a wide range of contributions from partners. The very nature of this work cries out for a system to manage these complex tasks well.

Once stem cell firms sell these lines, they will need to track the characteristics of each one to learn how it may be modified to create additional products. Each firm will need access to highly scalable compute power and data storage. Data on genomic information could easily grow to several terabytes in size, given that the individual stem cell genome will require a gigabyte and that tests and analytic information could easily be 10 times or several 10s of times larger. Each firm will also need to provide partners and follow-on developers with secure and rapid access to key parts of the database about the main lines, particularly if they collaborate on new derivatives being tested in clinical trials. Updating and sharing this information in real time is a challenge.

Virtual Worlds with access to scaleable computing power and data storage resources can be the keys to success for stem cell firms. Commercial stem cell products might be limited in scope and in market appeal when they first emerge. Nevertheless, once they expand in size and application, platforms that provide for extensive computing power, collaboration, and scaleable data storage will be fundamental for their success.

The new fourth-wave industries could impact traditional industries as well. One possible impact would be to open the way for additional industries that have traditionally shied away from automating their operations to employ complex model-based computing. The economic gains made by fourth-wave industries could be so substantial that they might alter the way many other sectors operate.

The model of open collaboration among firms that characterizes these new industries could also set an example for other sectors. More industries might integrate their product development work with smaller, nimble, innovative partners. It is not clear whether there would be a distinct bias for smallness, but collaborations between large suppliers and manufactures could end up being more efficient.

Altering Product Development

Virtual Worlds, grid computing, and new compute ecosystems could lead to new products, processes, and services.

We’ve already alluded to the ways these technologies might help firms accelerate product design and development, such as by enhancing just-in-time and lean manufacturing. In part, these improvements result from collaborations among different groups within a firm or between a large firm and its partners or subcontractors all bringing design ideas and testing them while products are still at the “virtual” stage. This reduces the time and cost of new product development and results in refined, highly tested products.

The interaction with consumers that these technologies afford is invaluable to integrating their opinions into product and service development. Virtual Worlds provide a way for innovative ideas to be collected from consumers or product developers, whose inputs are usually not considered in the design stage. Social networking in and of itself can change established business patterns.

A second way that these new business ecosystems might change how products, processes, and services are developed is by facilitating continuous improvement and innovation. This would result from providing greater access to compute power and would permit a large number of firms to run nearly unlimited amount of tests on various components of a new product design. Reactions from consumers on the potential product or service might contribute to improvement and innovation—or steer the firm away from a dud.

New ecosystems also might unleash the concept of open innovation, which holds that companies must be amenable to obtaining ideas for innovation from a wide range of sources outside of their own research centers. They should "buy or license processes or inventions (i.e., patents) from other companies."[89] Any innovations that are not being incorporated in products or services should be spun off or licensed to other firms. Open innovation contrasts with closed innovation, where a firm uses only the internal knowledge it obtains within its own R&D operations.

Organizational Forms

There has been speculation by some business organization experts that collaborative systems will require new forms of organization. Charles Heckscher argues that the dominant organizations of the future will rely on collaboration networks, wide-ranging global networks of creation and production.[90] These new agile organizations will replace bureaucratic systems. But Heckscher notes that businesses do not yet understand how to manage more fleeting and unfixed collaborations, which means that a number of different organizational types may compete to arrive at the best structure.

Heckscher says the new emerging enterprise could be called a collaborative enterprise structure, a solutions-oriented organization that contrasts with the old bureaucratic corporation's focus on mass production.[91] These types of enterprises emphasize contributions versus top-down paternalism.

	20^{th} Century Firm	**Emerging Enterprise**
Strategy	Mass Production	Solutions
Structure	Bureaucracy	Collaborative Enterprise
Culture	Paternalism	Contribution

Firms that leverage resources around opportunities to create more "opportunity-driven enterprises" are collaborative enterprise models. [92] Heckscher points to structures that include fluid teaming, task force overlays, decentralized teams, and front-back-middle organizations.

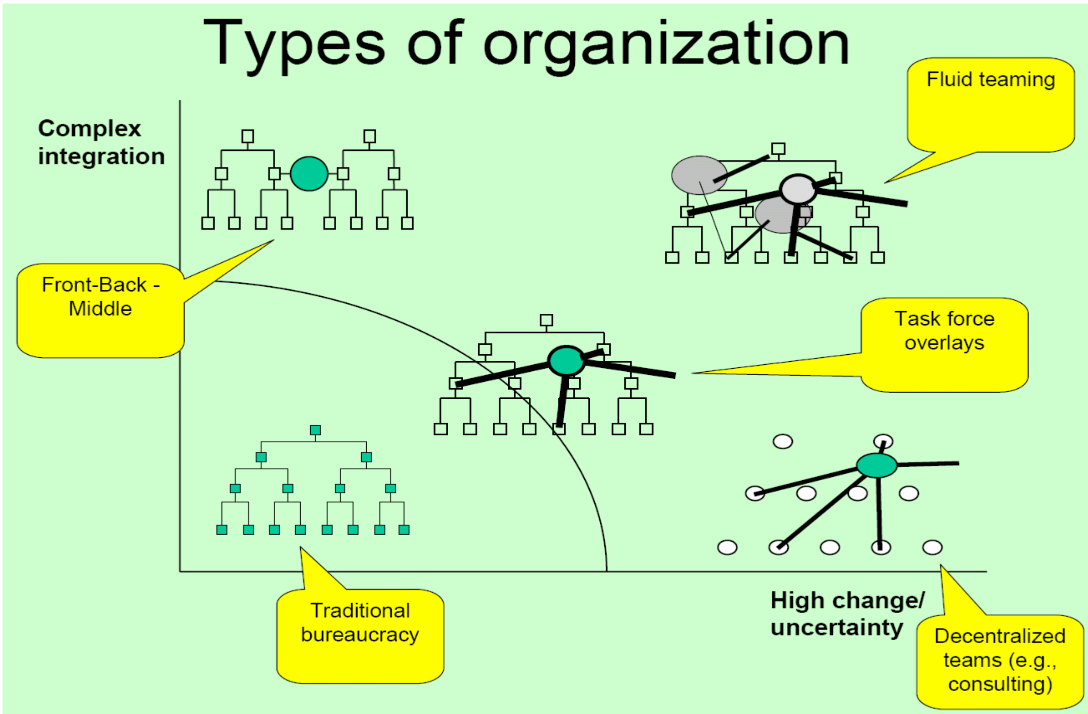

Figure 5. *The Collaborative Organization Project*. AKA "The Rutgers Network," http://www.heckscher.us/CWT/Collaboration%20network%20introduction.ppt. Accessed October 16, 2008.

An alternative approach to Heckscher's might draw less from the traditional multidivisional corporation and more from the need to create new structures that could easily link to "outside" contributors. This would mean that the main innovation in the new organizational forms would be to provide short-term or medium-term links with outside firms or organizations. Thus, the new structure would permit easy integration with independent business entities. This is the reason that modern guild system firms, discussed above, are proposed here as a likely organizational form.

Competitiveness and Collaboration

This section will explore how new technology-facilitated collaboration impacts U.S. business competitiveness—domestically and globally—and what needs to be done to speed deployment and adoption of these advanced tools and ensure that the U.S. captures the benefits of this technological shift.

Shifting to Collaboration

Virtual Worlds and on-demand computing will create a business environment where collaborative enterprises are the dominant form of business. Businesses across the range economic sectors—from industries in traditional sectors to those in the fourth-wave sector—are likely to benefit from the shifts toward collaboration.

This shift will very likely develop over the next decade in a series of phases. The first phase will use Virtual Worlds for education and training. The second phase will use Virtual Worlds for internal collaboration among corporate teams. The third phase will merge teams across business groups and across suppliers to develop a broader, collaborative enterprise.

During the first phase, there will be considerable experimentation with Virtual Worlds and little focus on tying Virtual Worlds to corporate applications for design and product development. Collaboration will focus on education and training or even substitute for conference calls and meetings. The main benefit will be savings in time and travel costs, but other benefits could include building teams that can focus on key problem areas within the firm.[93]

During the second phase, there is more internal learning and working with Virtual Worlds to exploit the benefits of collaboration. There has been little discussion of firms in this phase, but teaming and greater collaboration should result in efficiencies in time to market and in lowering the cost of developing new services and products.

The third phase will make Virtual Worlds central to the creation of new products and services. In traditional industries, collaborative enterprises will be able to design, test, and market new products and services at lower cost and in shorter time than is the case with traditional firms. They will gain efficiencies for several reasons. Collaborative groups within firms will be able to work more effectively on designs, testing, and product marketing, incorporating suppliers and partners as they work. They will overcome some of the constraints of design tools that are unable to interoperate by relying on a basic Internet operating system that runs Virtual Worlds, on-demand computing, and on-demand data storage. This operating system should evolve over the next few years and serve as the basic glue for computing, storage, and software technologies.

Virtual Worlds, cloud computing, on-demand storage, and next-generation networks will open up supply chains to a larger number of suppliers. Through these technologies and with new processes for closer collaboration, firms will be able to test new potential partners and bring them into the supply chain. New technologies also will make it easier to manage more partners in the supply chain and provide a better yardstick for evaluating the contributions and innovative capabilities of different suppliers. This might result in supply chains that are more competitive, less costly, and of greater value, leading to accelerated outsourcing. But it also might reverse outsourcing if a supplier's strong suit is its innovative capacity and knowledge rather than its low cost. This might reset the priorities of collaborative enterprises away from lowest cost to the highest innovation and level of knowledge.

Collaboration with suppliers and partners will be possible from the earliest stages of product design. This will add to the efficiencies in product development and testing. Ongoing inputs from customers will also ensure that new products are congruent with market tastes because emerging product designs will be test marketed in Virtual Worlds and via social networking sites. Suppliers and partners will capture these inputs and market tastes to become the preferred suppliers—not just those with the lowest price.

Additional efficiencies will be possible because workgroups around the globe will be able to collaborate in design, development, and marketing decisions, as well as respond to consumers. Global product platforms could be created that mirror market behavior, consumer preferences, or habits in groups of countries. At the same time, such platforms and subplatforms should provide ways for manufacturing firms or service companies to increase the number of common parts and processes in what they design and bring to market.

In addition, Virtual Worlds and model-based software could provide important new ways for collaborative enterprises to evaluate their profit-and-loss statements and financial position for a wide range of operations many times a day. This could be valuable when prices for different inputs are volatile, when markets change unexpectedly, or when the cost of capital shifts. The collaborative enterprise would be able to rapidly adjust the scale of its operations, the cost of its inputs and final products, the market where it sells its products, and the sources of its financing. This should result in lower operating and capital costs. The volatility of prices for inputs and greater need to manage the timeliness of their delivery is a major issue for producers. Market volatility is also a critical issue for service firms as abrupt shifts become more common.

There is also likely to be some downside in the move to Virtual Worlds. Since the new technology opens up the sensitive area of product design to many more collaborators, larger firms may be reluctant to adopt the technology until it is proven not to undercut their brand position or spur knockoff competitors. Until larger firms demonstrate the business value of Virtual Worlds—for instance, when they are successfully used for training, education, or meetings—there may be skepticism resulting in a general inertia in adopting new technologies. Firms that are not technology leaders will likely take even more time to adopt the sort of collaboration that would transform their firms.

In addition, it is possible that related technologies will take longer to develop than some analysts expect. The open platforms used by Virtual Worlds may remain closed or may take longer to develop. Interoperability between compute clouds may be delayed because firms such as Amazon or Microsoft want to build proprietary businesses that benefit from closed designs. There may not be the push toward open and interoperable cloud computing where end users pay for computing power as though it is a utility instead of a situation where the providers operate as oligopolies. Next-generation networks that support high-performance computing and model simulations for businesses operating in Virtual Worlds may take a long time to be deployed. Service providers may not have adequate incentives to create high-speed networks unless there is a massive shift to Virtual Worlds or a rapid growth of video-related applications on the Internet.

But there would also be interesting benefits for service firms that become collaborative enterprises. For instance, in the financial services industry, investment groups from different financial centers could meet in Virtual World locations or “sims” and immediately respond to market changes, evaluate how new decisions would affect exposure to risk, and reconvene rapidly if markets moved in unexpected directions. With a collaborative enterprise structure, financial institutions could include outside expert partners in certain types of financial instruments in their deliberations and, when appropriate, create joint investment strategies. Virtual World locations could gather and analyze data from a wide range of market trades or options investments in a matter of minutes, which would be extremely responsive to market shifts.

Consequently, service firms that become collaborative enterprises would be able to exploit some of the same efficiencies that would benefit manufacturing firms. They will be able to bring ideas together more rapidly and create products and services at lower cost. The ability to model products and processes using vast compute power could also change the depth of analysis and transform collaboration from an exchange of ideas or viewpoints into a more intelligent approach to defining innovative services based on modeling and simulation that might not have been available before. Firms that succeed in becoming collaborative enterprises may reduce the levels of management by reinforcing efficiency and cutting waste. Service firms could also specialize in innovative or more efficient services because they are attuned to the thinking around the design and product development priorities of their partner firms.

There could also be a disadvantage to Virtual Worlds in the services sector. Executives may have trouble learning how to employ Virtual Worlds to gain advantages in analyzing markets because they are less computer literate than newer employees. There might also be some infighting between different parts of a financial firm; a group that needs to make rapid decisions, such as capital markets, might be very supportive of Virtual Worlds, but another group, such as fixed investments, might want to take a more deliberative approach. In addition, there could be a reluctance to integrate groups that don’t usually collaborate into Virtual Worlds. In addition, it may take time to develop the person-to-person skills required for Virtual Worlds, which could slow the pace of change.

Nevertheless, Virtual Worlds, on-demand/cloud/grid computing, and next-generation networks could transform businesses to collaborative enterprises. This transition should spread across industrial and service firms. The main benefits are that a shift to Virtual Worlds and the related technologies would change the basic costs of operations as well as provide for efficiencies due to far more effective collaboration within and between firms and the ability to obtain more accurate information about consumer and market preferences. The shift to collaborative enterprises would also provide more effective means to incorporate many subsidiaries and partners into a large, global corporation that would be more agile and adaptive to change compared with its 20th century predecessor.

Entirely new industries,[94] "fourth-wave"[95] industries, might also be possible with the new range of technologies we describe above that support product design, testing, and development. A range of new industries could be created around the easy access to powerful computing.

How would such industries operate in ways that are different from traditional commodity, manufacturing, or service industries—those of the first, second, and third wave?

As was discussed earlier, one example is in the areas of regenerative medicine or the stem cell industry. This fourth-wave[96] industry would only be viable because of its ability to use Virtual Worlds, on-demand computing, on-demand storage, and innovative software. First, they need to be able to manage very complex product-development processes where enormous amounts of data are required to describe the initial stem cell line as well as all of the derived lines that a firm produces. Stem cell firms also need to manage their intellectual property, track descriptions of each basic stem cell line—how it might be modified to create new lines or variants that can address a range of diseases—and maintain information on a wide range of clinical trials. Stem cell firms also rely on collaborations with partners, research labs, hospitals, and clinical research organizations, which need easy access to designs, product development information, clinical trial results, and other data. Nearly every facet of the firm's operation—from product development and marketing to after-sales maintenance of information—would require extensive collaboration underpinned by foolproof quality controls.

Other firms in complex industries with many moving parts, such as energy or biotechnology, could also be Virtual World early adopters.

Competitive Impacts of Collaboration-Promoting Technology

We posit here that American enterprises that embrace collaboration with Virtual Worlds and on-demand computing technology will improve their competitive positions worldwide by establishing structures that develop goods and services more efficiently.[97] If firms in other countries adapt to these technologies and practices more rapidly than U.S. firms, then they will outcompete their American rivals. Firms will succeed or fail in this new method of doing business based on how well their employees can work with collaboration technologies and how well corporations manage the deep organizational effects of cooperation. This includes incorporating social networking and other technologies that offer new players a way to participate in design, development, marketing, and other tasks that result from this new enriched form of collaboration.

While we cannot foresee all of the ways that collaboration will affect the global economy, we can extrapolate from the discussion in the previous sections to predict the ways competitiveness might be impacted by future product development, management practices, and organizational structures based on collaboration. Certainly, collaboration and its impact on competitiveness will be shaped by the developments in Virtual Worlds, cloud computing, and on-demand and high-speed networking that are culminating in new technological capabilities for businesses and consumers. It should be emphasized that the use of open systems and standards as well as open and user-controlled networks are important elements of the transformation.

What may happen in terms of business processes and organizational change over the next decade or two could be just as transforming as the changes that Alfred Chandler described at the time the modern corporation was born.[98] As has been suggested, the global economy could experience a series of transformational changes.

These changes would be part of a fundamental transformation because they would alter the way businesses operate and how businesses interact with partners and consumers. This includes the way that all organizations develop products or services and the way they incorporate contributions from partners and suppliers as well as consumers. It also encompasses the way they market their goods and services and how they manage business processes, create products, and respond to consumer satisfaction after their wares and services are sold.

As we discussed previously, two types of collaborative enterprise might take hold. The first type, multi-industry conglomerates, would be marked by greater vertical and horizontal integration. Here, corporations would incorporate supplier networks into their own corporate structure to link the innovation and creativity of outside suppliers more closely to product development and testing. They might also merge across traditional industry categories if the final products were similar, creating new multi-industry corporations.

The second type of firm, the modern guild system, would be characterized by a tendency to retain supplier independence. These suppliers might link to Virtual Worlds to create products for a much wider range of final producers than they have traditionally served. This shift could be due to their ability to more readily contribute to product design and development activities in a range of firms as well as their ability to broaden the design and development skills of the affiliated corporations.

In either type of business arrangement, collaborative technology would alter firms' abilities to operate, manage, and structure interactions within their organizations. They would be able to bring vastly greater compute resources to bear on product and service development and investment decisions using Virtual Worlds powered by on-demand computing. Vast and scalable data stores, now available at low cost and for any size organization, would also level the playing field and enhance competitiveness. These shifts would also require new optical networks that offer users the ability to step up bandwidth availability with little difficulty. Finally, with new, multiprocessor computers, companies will be able to run new software that allows firms to model business operations and consumer behavior in a quantitative way—such as Intel's model-based computing product.

These changes suggest that global competitiveness will be based on the following four broad measures of change:

1. How extensively firms transform themselves to collaboration enterprises and adopt structures and strategies that are more open to incorporating partners, suppliers, and consumers in their operations and how rapidly such firms and industries become an important part of the existing economy. [99]

2. How rapidly collaboration enterprises adopt new compute-based technologies, such as Virtual Worlds, on-demand computing, multiprocessor technologies, and model-based software with the aim of altering the way they develop products and services.

3. How well equipped employees are to work in a collaboration enterprise world centered on partnerships, rapid innovation, and quick reactions to changes in markets and consumer tastes, including having the appropriate computer skills to function with Virtual Worlds, on-demand computing, model-based software, and on-demand software and data resources.

4. How strong the U.S. technology infrastructure is to support innovations in the fundamental technologies that support Virtual Worlds, on-demand computing and data storage, and model-based software so that they can sustain corporate productivity and transformation and growing consumer sophistication. Or will U.S. firms need to tap the technological resources of other economies that have more quickly built up important Virtual World capabilities and strengths in related technologies, such as on-demand computing, on-demand storage, and model-based software?

These measures suggest that the competitiveness of individual firms will be based on how rapidly they become global collaborative enterprises and how quickly they transform operations to use collaboration to improve the efficiency of designing, testing, and marketing products and services.

We believe that a fundamental change in the economics of producing services and goods can emerge alongside the adaptation of new synergistic technologies.[100] This has not yet occurred, however; rapid advances in social networking, computing, storage, software, and networks must still converge with widespread alterations in corporate business practices.

But technological advancements will allow firms to more rapidly transform their practices. The Internet is becoming three-dimensional via Virtual Worlds and the use of vastly more powerful processors. Data storage is beginning to exploit virtualization technologies and on-demand structures. Model-based software is on the cusp of resolving important business problems in new ways. Rapid communications solutions make it possible for businesses to change. These advances will transform our economy and our business culture. In the future, we could see even greater changes as far more powerful information technologies are developed and applied to business operations and consumer habits. These changes will not only make collaboration a major feature of corporate operations but also offer greater access to consumer opinions and market reactions.

Still, it is important to point out the significant obstacles to success. Virtual Worlds operate without a strong legal framework for business users and consumers, something we already see in the Internet. There is also a lack an open platform for development[101] and no formal barriers that might make it more difficult for individuals to engage in pornographic and lewd behavior, although changes in the next year should block access from a corporate site to such sites. In addition, studies of efficient collaboration and technological and organizational change are needed, as are protocols and common tools for sharing knowledge.[102]

Concerns over security, control, management, and integration stand in the way of cloud computing in the enterprise.[103] Data users may need to cede control of their information to companies that provide computing on demand. Firms may feel that this is too big a shift from traditional practice or worry about how well sensitive information is protected.

Grid computing presents businesses with similar conundrums since many firms do not see this as a traditional technology but one that is different and is to be owned by a business unit. While Amazon, Google, and other firms proved that this idea is wrong—showing that third-party grids can be tapped for specific projects and relinquished by the firm—other obstacles, such as a lack of skill sets for grid-specific tasks or a resistance from IT departments, are still present. Users also face a shortage of software development tools that are needed to build gridware applications.[104]

Actions of Other Governments

Although just a few governments have taken steps to promote Virtual Worlds, their efforts are substantial and impressive. There are also attempts to promote cloud and on-demand computing, but these are more likely to be at the research rather than the commercial level.

The most impressive effort in Virtual Worlds is the China Recreation District (CRD).[105] The goal of this project is to create the infrastructure that companies can use to sell products and services in Virtual Worlds. “The 80-square-kilometer complex [funded by the Chinese government] is huge, allowing for whatever physical needs the CRD may have including data centers, entrepreneurship centers, training facilities, a real-world amusement park, a game center and conference facilities."[106]

As of November 2007, there were 200 game and multimedia content producers on-site. The goal is to "bring 150 million middle-class Chinese people and companies into their virtual world platform," which is called "DOTMAN."[107] The platform serves as an enormous e-commerce site for selling final products. The platform includes six virtual spaces:

> DOTLIFE provides 3D models and databases for individuals and companies in the world; DOTBANK [is for] banking and transaction services; DOTMEDIA [is for] communications services; DOTSPACE [is for] content pooling, trading platforms, and libraries for 3D models, animations, films, games, and other digital content; DOTGAME [is for] online games; [and] DOTBASE [is for] Internet-related services from customer service to bandwidth.[108]

China Mobile, the largest mobile phone operator in China, is expected to offer incentives for its users to make purchases in this Virtual World, possibly offering one virtual dollar for every 100 minutes of calls. Evergreen Bank of China, in which the government owns a large stake, will establish a bank in the Virtual Worlds and offer clearance and settlement services to customers.[109]

Thailand is funding a $250 million Cyber City for media production and IT development.[110] This will include collaboration with Mindark, an extremely successful massive multiplayer online role-playing game firm, and Creative Kingdom, Inc. (CKI), which is a new planet in Entropia Universe that will provide a "diverse, entertaining and interesting virtual universe of vast proportions for participants to explore."[111] One hope is that "Cyber City will enable Thai workers to generate income from remote locations—thus revitalizing the economies of rural communities and stemming the crush of migration to urban centers."[112]

Government efforts to promote on-demand or cloud computing are limited in number and primarily focused on basic research. The European Commission and IBM are part of a 13-nation research effort called the RESERVOIR, which, according to the press release, "will introduce the new capabilities for the deployment of commercial service scenarios that cannot currently be supported."[113]

The Infocomm Development Authority of Singapore is also funding part of a global cloud computing test bed. The participants include HP, Intel, and Yahoo! as well as the U.S. National Science Foundation, the University of Illinois at Urbana–Champaign, and the Karlsruhe Institute of Technology (KIT) in Germany. According to the press release, this test bed:

> will provide a globally distributed, Internet-scale testing environment designed to encourage research on the software, data center management and hardware issues associated with cloud computing at a larger scale than ever before. The initiative will also support research of cloud applications and services.[114]

Government efforts in Virtual Worlds and on-demand computing are aimed at promoting research to support technological innovations and at priming the commercial use of Virtual Worlds, although China has moved the furthest in this regard.

Fostering U.S. Policy

In the United States, a number of players have different roles in promoting Virtual Worlds, including government, academia, and industry associations.

The government can support educational efforts to broaden the familiarity of the school-age and employed population with Virtual Worlds and cloud computing. It can build a new infrastructure for Virtual Worlds, on-demand computing, next-generation communications, and model-based software. It can directly promote efforts by firms to sell products and services in Virtual Worlds.

Government might also support experiments in training and industry-specific work with Virtual Worlds and cloud computing to see whether there is adequate understanding of the underlying technologies or problems accessing remote compute resources.[115] Government could also work with industry associations to create road maps that help individual firms transition to Virtual Worlds and on-demand computing. In addition, government could examine whether laws that govern the real world need to be modified to apply to issues that may arise in Virtual Worlds.

Academia is active in research on Virtual Worlds and on-demand computing, but it could begin to foster greater use of Virtual Worlds in teaching. This may require substantial training incentives for current faculty, but area-wide or department-level initiatives might help faculty teach more classes in Virtual Worlds.

Academia could also develop more collaboration with industry to foster greater use of Virtual Worlds in business.

Industry associations could develop training programs and seminars to help inform their members about Virtual Worlds and best practices in cloud computing. They might also work with academic institutions to create joint business–university seminars that would familiarize firms with these new technologies and promote their adoption.

Industry associations with members that are likely to be early adopters of Virtual World technologies could develop road maps to identify how business processes, such as design and testing, and business practices, such as collaboration with partners and suppliers, would be affected by Virtual Worlds. These road maps exist for technology development but have not been created to help businesses adapt to change.

Economic Development

We noted above the four dimensions that would lead to the widespread use of Virtual Worlds and on-demand computing in the U.S. If the U.S. economy's firms are among the first to transition to collaborative enterprises, if they have highly skilled employees who can work with Virtual Worlds and on-demand computing, and if academic institutions supply educated workers who are familiar with these new technologies, the U.S. economy would certainly benefit.

If Virtual World technologies are to become more integrated into business, U.S. economic development policies at the federal, state, and local level must ensure that they are not difficult for firms to adopt. State and local government might need to help regional and local firms obtain and master these technologies. A national effort might be required to help firms change their operations and underlying business technologies.

When Virtual Worlds are used for product design and service development together with on-demand, cloud, or grid computing, the number of firms in a regional supply chain could increase, leading to more competition and, possibly, churning. Local and regional firms could arrange themselves into industrial clusters by expanding the number of firms collaborating together and extending the geographical reach of partner networks using Virtual Worlds. Geographical reach of certain industries could be expanded if Virtual Worlds enable corporations to create large-firm supplier networks or clusters of skilled guild-like suppliers and partners.

The role of government, however, may have to change to nurture such developments. Regional planning associations, which traditionally confine economic development policies to particular geographic areas, might need to broaden their scope. The rise of Virtual Worlds would mean that local and regional firms would not only have to adopt new technologies, but be ready to join networks of large multinational firms that seek suppliers from around the nation and the world. As a consequence, regional firms would need to look beyond their neighborhoods for new U.S. or even global partners that enhance their collaboration skills and market position. We might see a breakdown of single-location clusters in favor of clusters that link several regions and are closely tied by industry history or skill sets (e.g., areas that emphasize engineering, software, and/or computing).

Policy Recommendations

Industry, academia, and political leaders need to recognize that Virtual Worlds could transform the U.S. and global economies as long as there are simultaneous adjustments in business practices, research and educational priorities, and government policies.

Government policy should focus on the fact that the U.S. will compete based on its ability to develop collaborative skills, not traditional business skills. Innovative policies should help corporations bring in social networking practices. Changes in the tax code could encourage investment in collaboration skills, networks of collaborative enterprises, and a new collaborative infrastructure. The federal government and states should also promote policies to promote faster development of cloud computing, scalable data storage, and open networks. They should also develop innovative training programs that educate businesses and employees about how to use collaborative technologies and integrate them into traditional disciplines.

Promoting the transformation will require policies that generate the following results:

- Heighten the awareness of business, labor, educators, and federal, state, and local politicians and authorities concerning the importance of Virtual Worlds and the collaborative enterprise to the economic competitiveness of the nation.

- Address the need for a technical infrastructure that can support Virtual Worlds and the collaborative enterprise and enhance the technology base of the U.S.

- Encourage corporations, business networks, and industry associations to adopt the use of Virtual Worlds and intensive compute resources.

- Provide economic development agencies with opportunities to work together to help firms and networks of firms adopt and deploy Virtual Worlds and intensive compute resources and that also help firms to insure their deployment and use in communities left behind.

- Assist business and government with identifying the measures that help firms and government agencies evaluate how well they are doing in adopting Virtual Worlds and intensive compute resources.

- Identify the education and training that employees and businesses will need if they are to successfully work as collaborative enterprises with Virtual Worlds and intensive compute resources.

- Promote the international collaboration of U.S. businesses with foreign firms through the use of Virtual Worlds and compute-intensive resources.

The first important policy recommendation is to explore the likely impact of such changes in the Internet, the way citizens and businesses access compute power and storage resources, and the resulting strain on communications networks. The recently created National Center for Research in Advanced Information and Digital Technologies begins this research process.[116] Businesses and the public need more information about how Virtual World-based ecosystems will reshape the U.S. economy and the type of job skills that will be required of workers. While the National Academy of Sciences has examined collaboration from a scientific vantage point, it has not taken a broader look at how collaboration enterprises and Virtual Worlds might transform the U.S. workforce as a whole.

The second set of policies is those that address the need for a technical infrastructure that can support Virtual Worlds and the collaborative enterprise and enhance the technology base of the U.S. The federal government, private companies, and industry associations need to work together to develop policies that ensure that future Virtual Worlds develop with open platforms and open standards. Having more than one open platform and extensive open standards that can be used to develop applications rather than having platform specifications controlled by cloud-computing or other Web 2.0 firms would stimulate the creation of a wide range of new applications.

The federal government and states should also promote policies to encourage faster development of cloud computing, scalable data storage, and open networks. Federal agencies, such as NASA, the Department of Defense, and the Department of Health and Human Services (HHS), could sponsor demonstration projects that employ Virtual Worlds to improve collaboration between suppliers and end manufactures in a variety of policy areas, including space, health, and defense. Particularly with HHS, these efforts could also involve the end users of these services—the citizens of the U.S.—who can give immediate feedback on ways to improve the development and delivery of services through Virtual Worlds.

Government agencies involved in the future development of the Internet, such as the U.S. Department of Commerce (DOC) and Defense Advanced Research Projects Agency (DARPA), could sponsor university–industry efforts to create pilot projects that use Virtual Worlds/Web 3D in training, education, and product design.

Policies funded by DARPA or DOC's Manufacturing Extension Partnership could support government–industry associations with the exploration and evaluation of how Virtual Worlds improve product development and services between suppliers, end manufacturers, or service providers. These collaborations could also be linked to state programs to improve the use of new technology.

Furthermore, several specific steps should be taken to enhance the technology base of U.S. corporations. This could include support for "soft" technologies that would help firms improve the technologies used for Virtual Worlds, providing the means to make Virtual Worlds based upon open standards and creating ways to make them more secure, more interoperable, and more able to support the creation of content that can be used on a number of different Virtual World platforms. This could also include support for similar open standards and interoperability of cloud computing, on-demand computing, and grid computing, as well as on-demand storage.

However, by virtue of their technical complexity, these technologies could pose significant barriers to linking computing and storage to Virtual Worlds. These considerable barriers must be addressed, and open standards and the open standards environment form the critical foundation for overcoming these disparate and diverse barriers.

Tax policies could also speed these transformations. Tax benefits might be offered to firms that adopt Virtual World environments, including tax credits for businesses that invest in collaboration technologies and explore how they can improve the processes to create new products and services. Tax policies could encourage the creation of open standards in Virtual Worlds, Web 2.0, cloud computing, and on-demand storage to create interoperable Virtual World business platforms.

National-level commissions or bodies, such as the President's Council of Advisors on Science and Technology (PCAST), could establish the parameters for the development of open platforms in concert with the National Science Foundation, the Software Industry Association, and major Virtual World companies, such as Second Life, Google, Microsoft, Oracle, VMware, and others.

Also, as part of this effort, there is a compelling need for major efforts to make it possible for businesses to use Virtual Worlds outside corporate firewalls. This has been a major factor slowing business adoption of Virtual Worlds. Even the use of "gray areas" has not proven to be a successful approach to creating secure islands outside of corporate firewalls.

In helping firms to insure their deployment, there is an opportunity to also focus on use in communities left behind. Here there is a role for economic development agencies. These agencies could identify opportunities to work together to help firms and networks of firms adopt and deploy Virtual Worlds and intensive compute resources—with special assistance and incentives for deployment in areas that have been left out of the economic mainstream.

Policies are needed to help business and government identify the measures that help firms and government agencies identify how well they are doing in adopting Virtual Worlds and intensive compute resources. For firms, the Malcolm Baldrige National Quality Award might add criteria for such measures, while for government agencies, the Department of Commerce has the data-gathering and analytic resources to begin to assemble measures and coordinate efforts in other government agencies.

The federal government should promote policies that focus on the four main indicators that are likely to enhance this nation's competitive status in the Virtual World economies of the future. The first group of policies should focus on ways that firms can transform themselves into collaboration enterprises. The second group of policies should focus on how rapidly collaboration enterprises can adopt new computer-based technologies. The third group of policies should address how well equipped employees are to work in a collaboration enterprise world. The fourth group of policies should focus on strengthening the technology base of the U.S. economy and creating a suitable environment for the operation of Virtual World technology.

Improving the skills workers need to have to work in a digital environment is another area of needed policies. This could include initiatives to improve the digital and social networking skills of employees so that they can work with collaborative environments such as Virtual Worlds. This might be part of new programs sponsored by federal agencies, such as the Department of Labor, and state training agencies. In addition, there could be new programs in primary and secondary schools as well as universities to help students learn more computer and software skills, including working with Virtual Worlds.

Primary and secondary schools as well as universities could beef up their courses in computers and software, adding in Virtual Worlds programs where possible. The U.S. National Science Foundation could establish summer teacher-training programs and encourage actively employed or retired computer experts to work with schools and universities to expand Virtual World skills.

New policies to create innovative training environments that emphasize collaboration skills within and between corporations and their suppliers or within specialized service firms should be established. This new type of training might be most effectively developed as a collaborative effort involving industry associations and the government, with the participation of Virtual World software vendors.

Education and training initiatives could focus on firms with extensive supplier-end manufacturer ties, and could be funded by the National Center for Research in Advanced Information and Digital Technologies. The Department of Defense might also require its suppliers and manufacturers to shift education and training toward new technologies, including the design of new aircraft and military products, in Virtual Worlds. Officials could evaluate new designs and “proof of performance” could be reviewed by going back through records of designs created in Virtual Worlds by the suppliers and end manufacturers.

Finally, policy initiatives should identify ways that U.S. international policies can promote collaborative environments and work with other nations to build skills for collaboration in their firms and workforces. Such policies could include the development of international systems of collaboration and equitable rights for new intellectual property.

Conclusion

New information technologies, such as Virtual Worlds, cloud/on-demand/grid computing, on-demand storage, and next-generation networks are creating immersive and collaborative environments, transforming the global business environment, and revolutionizing the traditional determinants of competitiveness

Advancements toward greater use of Virtual World technologies should be tracked by assessing how extensively firms transform themselves into collaboration enterprises and adopt structures and strategies that incorporate partners, suppliers, and consumers into product and service development operations.

The speed at which collaboration enterprises adopt new compute-based technologies will determine how quickly and thoroughly they alter the development and delivery of products and services.

Employees must be able to acquire new interpersonal and technological skills to work effectively in collaboration enterprises that focus on partnerships, rapid innovation, and quick reactions to changes in markets and consumer tastes.

And the U.S. technology infrastructure needs to support Virtual Worlds, on-demand computing, on-demand data storage, and next-generation networks to sustain corporate growth and respond to the sophistication of consumers.

U.S. tax, employment, and education policies will have to shift focus toward developing skills in collaboration and social networking in businesses and the workforce. New national initiatives are needed to build collaboration capabilities and to support more widespread use of Virtual Worlds. Success means we'll be well on our way to developing the high-tech, high-wage economy that will sustain America's competitiveness in the global economy for decades to come.

Endnotes

[1] Other authors have noted how that direct feedback from users can significantly enrich the design process and lead to innovative and unexpected results, including von Hippel, E. *Democratising Innovation.* http://web.mit.edu/evhippel/www/democ1.htm. Accessed October 3, 2008. The argument here is that collaboration as well as direct feedback and social networking within the firm will transform business.

[2] A study by Booz Allen Hamilton has pointed to the small number of firms that are able to achieve value from the global research networks they have established. This could be due to the difficulty of managing and coordinating participants in these networks and creating a single innovation platform. See Doz, Y., K. Wilson, S. Veldhoen, T. Goldbrunner, and G. Altman. *Innovation: Is Global the Way Forward?* INSEAD and Booz Allen Hamilton, 2005.

[3] This term is used by Forrester and other consulting groups, although the term Virtual Worlds or immersive environment is used more frequently. Driver, E. (with Moore, C., P. Jackson, T. Keitt, C. Schooley, and J. Barnett), *Web3D: The Next Major Internet Wave*, Forrester Research, April 18, 2008. http://www.forrester.com/Research/Document/Excerpt/0,7211,45257,00.html. Accessed Oct. 3, 2008.

[4] Ibid.

[5] These ideas are explored in Ondrejka, C. Education Unleashed: Participatory Culture, Education, and Innovation in Second Life. *The Ecology of Games: Connecting Youth, Games, and Learning*. (K. Salen, ed.), The John D. and Catherine T. MacArthur Foundation Series on Digital Media and Learning. The MIT Press, Cambridge, MA, 2008, pp. 229–252.

[6] Ibid, pp. 230–231.

[7] Ibid.

[8] Ibid.

[9] The author would like to thank Claus Nehmzov for suggesting this point.

[10] Ondrejka, C. Collapsing Geography: Second Life, Innovation, and the Future of National Power. *Innovations*. Vol. 2, No. 3, Summer 2007, p. 33.

[11] Doz, Y., K. Wilson, S. Veldhoen, T. Goldbrunner, and G. Altman. *Innovation: Is Global the Way Forward?* INSEAD and Booz Allen Hamilton, 2005.

[12] Booz Allen Hamilton, *The Growth of Global Innovation Networks Creates New Management Challenges*, http://www.boozallen.com/capabilities/services/services_article/3220998. Accessed Oct. 3, 2008.

[13] Ibid.

[14] Ondrejka, C. Collapsing Geography: Second Life, Innovation, and the Future of National Power. *Innovations*. Vol. 2, No. 3, Summer 2007, p. 33.

[15] Parris, C. *Online Virtual Worlds: Applications and Avatars in a User Generated Medium.* Testimony before the House Committee on Energy and Commerce, Subcommittee on Telecommunications and the Internet. April 1, 2008. http://energycommerce.house.gov/cmte_mtgs/110-ti-hrg.040108.VirtualWorlds.shtml. Accessed Oct. 3, 2008.

[16] Lucia Gradinariu, advisor for Industry Programs at Computer Associates, and a member of the Service Delivery Framework program of the TeleMangement Forum noted that in her Ph.D. experiments (at INSA de Lyon) in computer-mediated environments that are similar to Virtual Worlds, it was important to permit all users to be able to follow others' actions if collaborations were to be successful. Email note from L. Gradinariu to the author, Oct. 18, 2008.

[17] Rosedale, P. Testimony before the House Committee on Energy and Commerce, Subcommittee on Telecommunications and the Internet. April 1, 2008. http://energycommerce.house.gov/cmte_mtgs/110-ti-hrg.040108.VirtualWorlds.shtml. Accessed Oct. 3, 2008.

[18] The Stanford Virtual Human Interaction Lab has produced research on how avatars affect personal behavior. Some of the more interesting work is in Yee, N., and Bailenson, J., The Proteus Effect: The Effect of Transformed Self-Representation on Behavior. *Human Communication Research,* Vol. 33, pp. 271–290.

[19] Platoni, K. Stanford professor shows how avatars mimic behavior. *Stanford Magazine* November 11, 2007. http://storybank.stanford.edu/stories/stanford-professor-shows-how-avatars-mimic-behavior. Accessed Nov. 18, 2008.

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[25] Ibid.

[26] Chae-Sub, L. International Telecommunication Union. *NGN Developments in ITU-T.* HSN 26–28 January 2005, Jeju, Korea. http://mmlab.snu.ac.kr/links/hsn/workshop/hsn2005/document/session1/1_3.pdf. Accessed Oct. 4, 2008.

[27] Mangini, D. Leveraging the SDP for Growth: Relating SDP Capabilities to the Evolving Telecom Business Model. Presented at IBM Global Telecommunications Industry Analyst Briefing, Austin, Texas, USA, 2007.

[28] Chae-Sub, L. International Telecommunication Union. *NGN Developments in ITU-T.* HSN 26–28 January 2005, Jeju, Korea. http://mmlab.snu.ac.kr/links/hsn/workshop/hsn2005/document/session1/1_3.pdf. Accessed Oct. 4, 2008.

[29] Here we emphasize how these factors will reshape corporate strategy and structure as well as business organization. One could also argue that these changes will have a profound effect on the business ecology and the capturing of knowledge and know how. Whether individuals or groups of individuals, suppliers, or customers, these entities will capture both codified and tacit knowledge and, depending on the structure of the groups and the ownership of the knowledge, spillover effects will permeate the supply chain.

[30] Method, *Cigna Case Study*. http://method.com/#/detail/CaseStudy/44. Accessed November 16, 2008.

[31] *'Not a Site, but a Concept': Tapping the Power of Social Networking*. July 9, 2008. http://knowledge.wharton.upenn.edu/article.cfm?articleid=2009. Accessed Oct. 3, 2008.

[32] Security protocols, open standards, and attaining agreed-upon levels of formal quality of service are factors that have slowed the adoption and deployment of grid computing. We hope to emphasize the following points in this discussion: first, that a lack of agreement on security and standards has slowed grid adoption; and second, that the emergence of Virtual Worlds, social networking, cloud computing, and new types of software, will allow businesses to gain enough from the efficiencies and from the confluence of new technologies that there will be a great deal of pressure to overcome a large number of previous barriers to adoption and that many of the technical challenges that once posed serious problems will no longer be "deal breakers" on the road to full utilization.

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[47] Boeing 787 Dreamliner Program Uses DELMIA, CATIA, ENOVIA. PLM News, Dec. 13, 2006. http://www.eng.fea.ru/FEA_news_370.html. Accessed Oct. 3, 2008.

[48] Ibid.

[49] Driver, E. Web3D: The Next Major Internet Wave. *Forrester Research, Inc.,* April 18, 2008, p 10.

[50] Byron Reeves, the Paul C. Edwards Professor of Communication at Stanford University and co-founder of Seriosity, Inc., quoted in IBM and Seriosity. *Virtual Worlds, Real Leaders: Online games put the future of business leadership on display*. A Global Innovation Outlook 2.0 Report, p. 5. A separate IBM paper (DeMarco, M., E. Lesser, and T. O'Driscoll, *Leadership in a distributed world: Lessons from online gaming.* IBM Institute for Business Value, 2007), discusses the same analysis.

[51] Virtual Worlds, *Real Leaders: Online games put the future of leadership on display.* A Global Innovation Outlook 2.0 Report. IBM and Seriosity. http://www.ibm.com/ibm/ideasfromibm/us/giogaming/073007/index1.shtml. Accessed Oct. 3, 2008.

[52] Baxter, A. A Leap into the Virtual World. *Financial Times*, Feb. 29, 2008.

[53] Ibid. Note that the MIT Sloan Leadership Model defines "four core capabilities needed for effective leadership: *sensemaking*—the ability to make sense of ambiguous situations; *relating*—developing key relationships within and across organizations; *visioning*—creating compelling images of the future; and *inventing*—turning visions into reality."

[54] Trondsen, E. Collaborative Work in Virtual Worlds. Presented at vBus Expo, April 26, 2008.

[55] It is certainly possible that Virtual Worlds could increase the time to market and perform critical business processes if they are not developed properly. In contrast, the architecture of many Virtual Worlds involved with critical business processes would include a large number of feedback processes and connections to people providing inputs and oversight. If these people play their proper roles and software and compute power help them refine processes, the firm should gain efficiencies. If these things are not properly structured and managed, the results could certainly be different. Some of the difficulties firms such as Airbus have faced resulting from product lifecycle management should be overcome if Virtual Worlds are incorporated in the process. But Virtual Worlds do not guarantee success unless they begin to include highly intelligent controls over processes that would undermine the main intent of what they hope to accomplish.

[56] Trondsen, E. Collaborative Work in Virtual Worlds. Presented at vBus Expo, April 26, 2008. Trondsen's chart of the speed of adoption of Virtual Worlds for collaborative work in different sectors finds that these two sectors are the most rapid adopters, with academia close behind. The financial services industry seems likely to lag behind, although high-tech manufacturing ranks just behind academia.

[57] This picture of more sophisticated applications not only conforms to Intel's vision for model-based computing but also reflects other visions of computing and software that address very complex issues. A similar vision of growing computer and software sophistication is discussed in *Advanced Scientific Computing Research: Delivering Computing for the Frontiers of Science.* Office of Science, U.S. Department of Energy. http://www.er.doe.gov/ascr/About/ASCRstrategicplan073004final.pdf. Accessed Oct. 6, 2008.

[58] Intel. *Model-based Computing: Harnessing the Power of Tera-scale Systems.* http://techresearch.intel.com/UserFiles/en-us/Image/TS-docs/whitepapers/ModelBasedComputing_061907.pdf. Accessed Oct. 6, 2008.

[59] Koehl, S. Rattner's Virtual World's Keynote: Research Reflections on IDF Day 3. Research@Intel blog, Sept. 21, 2007. http://blogs.intel.com/research/2007/09/rattners_virtual_worlds_keynot.php. Accessed Oct. 6, 2008.

[60] Cremorne, L. Interview: David Rolston, Forterra CEO. *The Metaverse Journal*, June 5, 2008. http://www.metaversejournal.com/2008/06/05/interview-david-rolston-forterra-ceo. Accessed Oct. 3, 2008.

[61] Johnson, P., and B. Duplat. Giving Life to 3D With 3DVIA. Presented at Dassault Systèmes Analyst Day, Paris, June 2006. http://www.3ds.com/corporate/investors/presentations. Accessed on Oct. 6, 2008.

[62] Fontana, J. Merrill Lynch Going Stateless. *Network World*, Aug. 11, 2008, p. 18.

[63] Birnbaum, J. as quoted in Fontana, J. Merrill Lynch Going Stateless. *Network World*, Aug. 11, 2008, p. 18.

[64] Amazon Web Services. Case Study: Digitaria. http://www.amazon.com/b?ie=UTF8&node=497904011. Accessed Oct. 6, 2008.

[65] The European Commission's VIVACE Project for the aircraft industry promoted efforts to improve PLM and to make it easier to access data at different points in the cycle. See VIVACE Forum 1, EADS Use Cases, Sept. 20–21, 2005.

[66] Jackson, C. Complementary Physical and Digital Prototyping Strategies: Avoiding the Product Development Crunch. *Aberdeen Group*, Feb. 2008. http://images.autodesk.com/adsk/files/digital_prototyping_benchmark_report.pdf. Accessed Oct. 6, 2008.

[67] Boeing 787 Dreamliner Program Uses DELMIA, CATIA, ENOVIA. *PLM News*, Dec. 13, 2006. http://www.eng.fea.ru/FEA_news_370.html. Accessed Oct. 6, 2008. See also the discussion in the previous chapter.

[68] Cohen, R. Collaboration Grids: Virtual Products and Business Benefits. Economic Strategy Institute. http://www.econstrat.org/index.php?option=com_content&task=view&id=299&Itemid=46. Accessed Oct. 6, 2008.

[69] Chandler, A. Standard Oil Company (New Jersey): Ad Hoc Reorganization. In *Strategy and Structure: Chapters in the History of the American Industrial Enterprise.* Anchor Books, New York, 1966, pp. 228–277.

[70] This idea is similar to project-based or project-led organizations. The project-based organization gathers disparate firms together on a temporary basis as part of a particular project. In the film industry during the 1930s and 1940s, the studio system included all the different firms and individuals under one roof, but the post-1950s system relied upon independent contractors very much like the guild system we discuss here. Many other types of firms can also fall under what David Stark has called "permanently beta." For example, advertising firms are project-driven organizations in which some firms have enormous resources in-house while other, typically smaller, firms have a network of external suppliers. We argue here that Virtual Worlds make it possible for more traditional organizations to overcome the lack of "engagement" that the temporary ties in project-led or project-based organizations create. On the studio system, see Schatz, T. *Boom and Bust: American Cinema in the 1940s*. University of California Press, Berkeley, CA, 1999. For David Stark's writings, see: Neff, G., and D. Stark. *Permanently Beta: Responsive Organization in the Internet Era.* Center on Organizational Innovation, Columbia University, September 2002.

[71] Clabby Analytics. *The Data Center "Implosion Explosion" . . . and the Need to Move to a New Enterprise Data Center Model*, Feb. 2008. http://www-03.ibm.com/systems/resources/systems_optimizeit_datacenter_pdf_nedc.pdf. Accessed Oct. 6, 2008.

[72] The parallel between the rise of the electrical utility industry and the emergence of on-demand computing as well as software-as-a-service is the key theme of: Carr, N. *The Big Switch.* Norton, New York, 2008. Carr does not indicate many of the implications for industrial structure very clearly.

[73] Microsoft Windows Live VP Debra Chrapaty as quoted in O'Reilly, T. Open Source and Cloud Computing. *O'Reilly Radar,* July 31, 2008. http://radar.oreilly.com/2008/07/open-source-and-cloud-computing.html. Accessed Oct. 6, 2008.

[74] O'Reilly, T. Open Source and Cloud Computing. *O'Reilly Radar,* July 31, 2008. http://radar.oreilly.com/2008/07/open-source-and-cloud-computing.html. Accessed Oct. 6, 2008. There is some evidence that Red Hat is trying to make cloud computing more open source. See Byron, D. Open Source into the Cloud at the Red Hat Summit. *Ebiz,* June 20, 2008. http://www.ebizq.net/blogs/open_source/2008/06/open_source_into_the_cloud_at_1.php. Accessed Oct. 6, 2008.

[75] O'Reilly, T. Open Source Paradigm Shift. O'Reilly.com, June 2004. http://www.oreillynet.com/pub/a/oreilly/tim/articles/paradigmshift_0504.html. Accessed Oct. 6, 2008.

[76] Carr notes that "one of the fundamental economic characteristics of Web 2.0 is the distribution of production into the hands of the many and the concentration of the economic rewards into the hands of the few. It's a sharecropping system, but the sharecroppers are generally happy because their interest lies in self-expression or socializing, not in making money, and, besides, the economic value of each of their individual contributions is trivial. It's only by aggregating those contributions on a massive scale—on a Web scale—that the business becomes lucrative. To put it a different way, the sharecroppers operate happily in an attention economy, while their overseers operate happily in a cash economy. In this view, the attention economy does not operate separately from the cash economy; it's simply a means of creating cheap inputs for the cash economy." Carr, N. Sharecropping the Long Tail. *Rough Type,* Dec. 19, 2006. http://www.roughtype.com/archives/2006/12/sharecropping_t.php. Accessed Oct. 6, 2008.

[77] There is excellent work on open standards for Virtual Worlds. One good explanation of some of these efforts is Levine, A. Metanomics This Week: David Levine and IBM Virtual Worlds. *NMC Campus Observer,* March 3, 2008. http://sl.nmc.org/2008/03/03/metanomics-ibm. Accessed Oct. 6, 2008. There is also a working group of the Motion Picture Experts Group (MPEG) within the International Organization for Standardization (ISO) that has published a working paper: Information Exchange with Virtual Worlds: Context, Objectives and Use Cases. ISO/IEC JTC 1/SC 29/WG 11/MXXXX, Shenzhen, China, October 2007. http://www.chiariglione.org/mpeg/working_documents.htm. Accessed Oct. 6, 2008. This work is to establish standards for bringing video and other information into Virtual Worlds.

[78] O'Reilly, T. Open Source and Cloud Computing. *O'Reilly Radar,* July 31, 2008. http://radar.oreilly.com/2008/07/open-source-and-cloud-computing.html. Accessed Oct. 6, 2008.

[79] Carr, N. *The Big Switch: Rewiring the World, from Edison to Google*. W. W. Norton, New York, 2008.

[80] Nelson, M. and C. Francis, The 3D Internet and Its Policy Implications, Telecommunications Policy Research Conference 2007. http://explore.georgetown.edu/publications/29942. Accessed Oct. 20, 2008.

[81] O'Reilly, T. Open Source and Cloud Computing. *O'Reilly Radar,* July 31, 2008. http://radar.oreilly.com/2008/07/open-source-and-cloud-computing.html. Accessed Oct. 6, 2008.

[82] David, P.A. The Dynamo and the Computer: An Historical Perspective on the Modern Productivity Paradox. *The American Economic Review*, Vol. 80, No. 2, Papers and Proceedings of the Hundred and Second Annual Meeting of the American Economic Association, May 1990, pp. 355–361. David's essay emphasizes the long time that it took for electricity to be adopted widely and compares it to the adoption of the computer. It may be possible that the skills needed for the use of Virtual Worlds and other new technologies will be far more widespread in the United States and other populations because of the enormous number of game players. This could mean that the adoption of the new technologies discussed here will be more rapid than many business observers might assume and that the widespread experience with social networking will make demands for open systems and standards much more effective than they have been in the real economy.

[83] This section is based on Cohen, R. Collaboration Grids: Virtual Products and Business Benefits. *On-Demand Enterprise,* Oct. 23, 2006. http://www.gridtoday.com/grid/997970.html. Accessed Oct. 6, 2008.

[84] See the R. Cohen articles, Speeding up Aircraft Design and Driving Virtual Car Design. *Grid Computing Now!* Dec. 22, 2006. http://grid.globalwatchonline.com/epicentric_portal/site/GRID. Accessed Oct. 6, 2008.

[85] Cohen, R. BMW and Grids: A Case Study. *Grid Computing Now!* March 28, 2007. http://grid.globalwatchonline.com/epicentric_portal/binary/com.epicentric.contentmanagement.servlet.ContentDeliveryServlet/GRID/Whos percent2520Using percent2520Grid/Case percent2520Studies/Case percent2520study percent2520PDF percent2520files/BMW percent2520pdf percent2520version.pdf. Accessed Oct. 6, 2008.

[86] Cohen, R. Driving Virtual Car Design. *Grid Computing Now!* Dec. 22, 2006. http://grid.globalwatchonline.com/epicentric_portal/site/GRID. Accessed Oct. 6, 2008.

[87] Ibid.

[88] Fellows, W. Getting Beyond the Compute Grid: The Challenge of "Grid 2.0." *On-Demand Enterprise*, Sept. 24, 2006. http://www.on-demandenterprise.com/features/getting_beyond_the_compute_grid__the_challenge_of__grid_2_0__07-29-2008_08_32_37.html. Accessed Oct. 6, 2008.

[89] The Love-in: The Move Toward Open Innovation Is Beginning to Transform Entire Industries. *The Economist*, Oct. 11, 2007. http://www.economist.com/specialreports/displaystory.cfm?story_id=9928227. Accessed Oct. 6, 2008. This article summarizes Henry Chesbrough's work on open innovation.

[90] Heckscher, C. *The Collaborative Enterprise: Managing Speed and Complexity in Knowledge-Based Businesses.* Yale University Press, New Haven, Conn., 2008. Other organizational writers who have explored similar themes include: Skyrme, D. J. *Knowledge Networking: Creating the Collaborative Enterprise.* Butterworth-Heinemann, London, 1999 and Campbell, A. and M. Goold. *The Collaborative Enterprise: Why Links Across the Corporation Often Fail and How to Make Them Work.* Basic Books, New York, 2000.

[91] Heckscher, C. From Bureaucracy to Collaborative Enterprise. In *The Collaborative Enterprise: Managing Speed and Complexity in Knowledge-Based Businesses.* Yale University Press, New Haven, Conn., 2008.

[92] Heckscher, C. The Collaborative Organization Project. The Center for Workplace Transformation, Rutgers University, May 8, 2001. http://www.cwt-ru.org. Accessed Oct. 6, 2008.

[93] Several examples of training and education using Virtual Worlds are available. AMD today uses its AMD Dev Central Pavilion on AMD Dev Central Island in Second Life (SL) to create a Virtual World environment that extends its Developer Outreach program in virtual space for meetings, lectures, training courses, and networking opportunities for developers. See AMD Opens Developer Pavilion in Second Life. *Virtual Worlds News,* Feb. 19, 2007. http://www.virtualworldsnews.com/2007/02/amd_opens_devel.html. Accessed Oct. 6, 2008.
Engineering & Computer Simulations (ECS) has developed an Emergency Management Nexus virtual collaborative environment to provide additional capability and functionality to the already-successful Joint State Response Training System (JSRTS) program for the U.S. National Guard. See ECS Expands National Guard Bureau Virtual World. Press release, May 29, 2008. http://www.ecsorl.com/news/news_NGBvirtualWorlds.html. Accessed Oct. 6, 2008.
Forterra Systems, Inc., has used virtual reality tools with its OLIVE Virtual Worlds platform to create the Virtual Highway Accident Training Application, which trains police, fire, EMT, towing recovery, and transportation officials in best practices of first responders to highway accidents on I-95. See U of MD's Virtual Highway Accident Training Application: University of Maryland Creates Virtual Highway Accident Training Application. http://www.forterrainc.com/index.php?option=com_content&task=view&id=54&Itemid=47. Accessed Oct. 6, 2008.

[94] Although some of these firms are compute-intensive or compute-centric, a large majority will exist in sectors that do not focus on computing. The discussion here cites the regenerative medicine or stem cell industry as one example because of the increasing complexity of designing and managing products and services. We could also have cited design intensive companies or firms that are developing and selling content on the Internet or in Virtual Worlds. It is not just these fourth-wave firms that will move into Virtual Worlds. We expect that many traditional agricultural, manufacturing, and services firms will adopt Virtual Worlds and that business will change in many ways as a result. Traditional firms, particularly if they do a good deal of design and development work or—in the case of banks—need to create new investment strategies very rapidly, should adopt Virtual Worlds, but we expect that Virtual Worlds will be employed for far more than compute-intensive activities in firms because of the economic and operational efficiencies and greater efficiencies in managing complex corporations.

[96] Economists describe industries as *primary, secondary,* and *tertiary* to reflect the fact that they are agricultural, manufacturing, and services. We categorize these industries as *first, second,* and *third wave.* We call the new computing companies as *fourth wave* because all their operations will be built on computing, not just specific parts. There are a few examples of firms that have been developed with the intent of having the entirety of their operations connected by computing and Web services, such as several small and innovative pharmaceutical firms, a few of which were created by executives from the computing or Web services industry, and a number of hedge funds, including firms such as SAC Capital.

[97] By this we mean technologies that support collaboration, such as Virtual Worlds, and the unlimited activites that these technologies can support with business partners and consumers so that they can participate collaboratively. We also mean that such activities can be enhanced and broadened, from the shared editing of documents to shared visualizations of data simulation to greater reliance upon consumer or partner inputs for the creation of new designs or services. However, the mere adoption of these technologies is not enough. The social adaptation of these technologies and learning to use them constructively will radically change the way people participate in work.

[98] Chandler, A. *Strategy and Structure.* Anchor Books, New York, 1966.

[99] This is true regardless of whether the new firms are multi-industry conglomerates or "modern guild system" firms, as discussed in section 3.

[100] This discussion does not purposefully overlook the significant obstacles, both technological and organizational, that are likely to retard the move to collaborative enterprises and the transformation we discuss here. Some of these may include whether Web 3D, the future Internet, is built on open standards and whether or not cloud computing is controlled largely by a small number of firms that appropriate the key benefits for themselves. The aim here is to describe the main parameters that would determine how well firms and countries will compete in a new economic environment.

[101] Dell, K. Second-Life's Real World Problems. *Time Magazine*, Aug. 9, 2007. http://www.time.com/time/magazine/article/0,9171,1651500,00.html. Accessed Oct. 6, 2008.

[102] Cummings, J., T. Finholt, I. Foster, C. Kesselman, and K. A. Lawrence. *Beyond Being There. A Blueprint for Advancing the Design, Development, and Evaluation of Virtual Organizations.* Final Report from Workshop on Building Effective Virtual Organizations , May 2008, p. 1. http://www.ci.uchicago.edu/events/VirtOrg2008/VO_report.pdf. Accessed Oct. 6, 2008.

[103] Martin, R. Moving to the Cloud, Businesses Encounter Turbulence. *Information Week*, June 26, 2008. http://www.informationweek.com/news/services/business/showArticle.jhtml?articleID=208800951. Accessed Oct. 6, 2008.

[104] Garretson, C. GridWorld: Panelists Weigh Grid's Promise, Obstacles. *Network World*, Sept. 13, 2006. http://www.networkworld.com/news/2006/091306-gridworld-keynote.html?page=2. Accessed Oct. 6, 2008.

[105] Sherman, C. China's Grand Virtual Worlds Plan—A First Hand Look. *Virtual Worlds News*, Nov. 26, 2007. http://www.virtualworldsnews.com/2007/11/a-close-look-at.html. Accessed Oct. 6, 2008.

[106] Virtual China: An Exploration of Virtual Experiences and Environments In and About China. *Virtual Worlds China, Association*. http://www.virtual-china.org/2008/07/22/virtual-worlds-in-china-association. Accessed Oct. 13, 2008.

[107] Ibid.

[108] Ibid.

[109] Sherman, C. China's Grand Virtual Worlds Plan—A First Hand Look. *Virtual Worlds News*, Nov. 26, 2007. http://www.virtualworldsnews.com/2007/11/a-close-look-at.html. Accessed Oct. 6, 2008.

[110] Thai Government and Architects Co-Launch Real and Virtual Building in Entropa; Leads to Movie Deal. *Virtual World News*, Feb. 19, 2008. http://www.virtualworldsnews.com/2008/02/thai-government.html. Accessed Oct. 6, 2008.

[111] Ibid.

[112] Ibid.

[113] IBM and Partners Launch European Union Cloud Computing Initiative: Building the Runway to Cloud Computing. Press release, Feb. 4, 2008. http://www.cetic.be/IMG/pdf/IBM_s_Reservoir_Press_Release.pdf. Accessed Oct. 6, 2008.

[114] HP, Intel and Yahoo! Create Global Cloud Computing Research Test Bed. IDA Singapore. Press release, July 29, 2008. http://www.ida.gov.sg/News percent20and percent20Events/20050906103951.aspx?getPagetype=20. Accessed Oct. 6, 2008.

[115] The U.S. government is supporting training in Virtual Worlds by the National Guard and extending these efforts to other agencies outside of the Department of Defense.

[116] The purpose of this center is to "support a comprehensive research and development program to harness the increasing capacity of advanced information and digital technologies to improve all levels of learning and education, formal and informal, in order to provide Americans with the knowledge and skills needed to compete in the global economy." See SEC. 802. National Center for Research in Advanced Information and Digital Technologies. http://www.fas.org/press/_docs/Advanced percent20Information percent20and percent20Digital percent20Technologies.pdf. Accessed Oct. 6, 2008.